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OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

LECTURES

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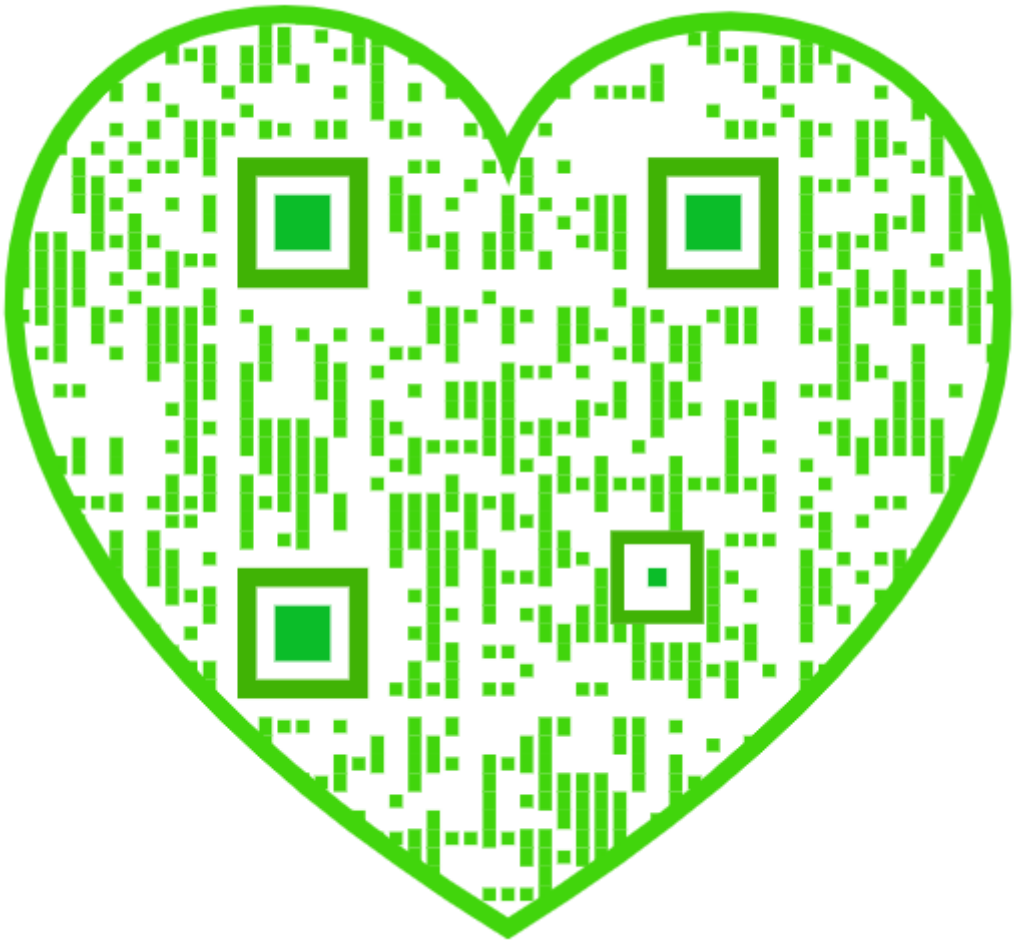

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OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lectures

WELDING AND CUTTING
WITH THE
OXY-ACETYLENE TORCH

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

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LECTURES

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Fred E. Rogers, Author of Lectures and Workroom Exercises.
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OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

COMBUSTION

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COMBUSTION

The Blacksmith's Forge—The Air Blast—Why the Blast Makes the Fire Burn Hotter — Welding — Fuels or Combustibles — Heat and Temperature — Oxygen, the Supporter of Combustion — Conditions Required for Perfect Combustion — The Oxy-Acetylene Torch.

You are to learn how to make welds with the oxy-acetylene torch and to study the construction and principles of the apparatus. These are simple but like many other simple matters they require clear understanding. Before taking up torch welding in detail, we will give a little study to the blacksmith's forge, and forge welding. If you first clearly comprehend the principles of the forge fire you can more easily comprehend the oxy-acetylene torch and its operation. You will see more clearly why it is such an efficient welding tool when handled by a skilled workman, and will be more likely to avoid making those mistakes that result in poor welds and waste.

The blacksmith welds two irons together by heating them in his forge until the ends are white hot and dripping, and then he beats them together on the anvil with rapid blows of his hammer. The blacksmith can make welds because his forge fire raises the iron to such a high temperature that it is melted on the surface and is soft like putty throughout. When he lays the two hot ends together they stick, and the hammer blows force the soft semi-liquid parts intimately together. The blacksmith depends first on getting the correct welding heat, and then on skillful hammering to make a sound weld. Hammering is necessary to make a good scarf weld when heated in the open forge, but other methods may be used to make a sound weld when the metal is at the fused or welding heat. Good butt welds may be made by simply forcing the ends together by pressure when at the proper welding temperature. Welding may be done in a furnace with no hammering or pressure at all except the weight of the metal itself. It is merely a matter of getting the metal hot enough, and keeping

the scale and foreign matter out of the weld. The semi-liquid metal will run together and be solidly united when cold.

Let us examine a blacksmith's forge and see what it consists of. The ordinary forge has a plate or table for a fuel bed. In the center of the table is an opening through which air is admitted from beneath. This part is called the tuyere. Connected with the tuyere by a pipe is a fan (or bellows) for forcing air through the tuyere to the fuel bed above. The fire is supplied with air from beneath; it burns fiercely if the air is forced through it rapidly.

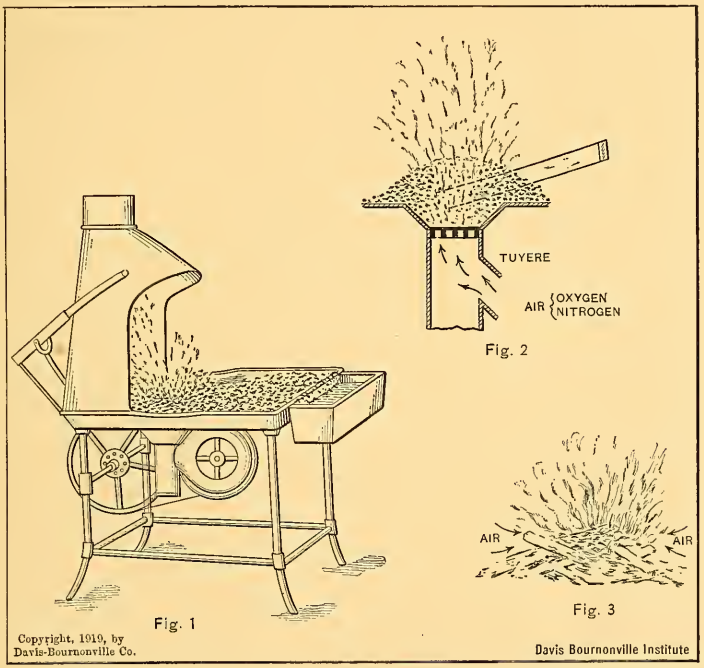
A much hotter fire is obtained in a blacksmith's forge than is possible in a fire built on the ground. The blacksmith can melt cast iron and burn steel. It is quite impossible to melt cast iron in an ordinary open fire. "Why is it possible to get so much greater heat in the blacksmith's forge?" The answer is—"Because the fire is fanned by the blast." "But why does fanning the blast make it burn hotter?" "Because it gets more air." But this does not really tell why. In order to explain the action clearly we must first give a little study to what fire is.

Combustibles or Fuels

We say fire burns. But what is it that burns or consumes? It is fuel in some form or other, such as wood, charcoal, hard coal (anthracite), soft coal (bituminous), coke, tar, petroleum, fuel oil, kerosene, gasoline, hydrogen, illuminating gas, acetylene, and in fact, anything combustible. All fuels are combustibles, which means that they are materials that burn in the atmosphere when raised to a sufficiently high temperature. Fire then is combustion. The temperature at which combustion begins, is called "the point of ignition." The ignition point varies with different materials. The ignition point of soft pine is comparatively low. Advantage is taken of this fact in making matches. A match is tipped with a point containing sulphur or some other chemical of comparatively low igniting point which burns freely. Over the end of the sulphur tip is a thin coating of phosphorus. Now phosphorus has a very low igniting point, and sufficient heat can be produced by drawing the match head over any rough surface to set it on fire. The phosphorus ignites, and in burning it produces a sufficiently high temperature to ignite the sulphur. That

in turn burns hot enough to ignite the soft pine stick, and there you have progressive action when you strike a match—a series of combustions, starting with the phosphorus and ending with the soft pine.

Anthracite, or hard coal, is difficult to ignite. It was, several years after anthracite was discovered in Pennsylvania before it was used as fuel at all. Nobody was able to burn it because no



THE BLACKSMITH'S FORGE AND THE OPEN FIRE COMPARED

one knew just how to set a mass of it afire or what were the conditions necessary for its continuous combustion. The claim is made that the conditions required were discovered by accident.

An open fire built on the ground, even if supplied with the most easily burned materials, soon reaches its maximum temperature, and no amount of new fuel supplied will preceptibly raise the temperature. You will get a much larger fire but not a hotter fire. Here is a very important point which should be clearly

understood. A large fire does not necessarily mean a very hot fire. The fuel bed or flames of a large fire may never rise much above a temperature of 2000 degrees Fahrenheit.

Heat and Temperature

We said that a large fire does not mean necessarily a very hot fire. There will be much heat given off but the temperature will not rise above a certain point. It is somewhat the same as a glass of ice water and a barrel of ice water. The glass of ice water is just as cold as the water in the barrel. If we had forty barrels of ice water they would be no colder than the glass full. So it is with a large and a small fire. The temperature of the small fire may be as high as the temperature of the large fire. The amount of heat given out by the large fire, however, will be more of course than given off by the small fire. The larger the fire the greater the amount of heat. But the temperature does not necessarily increase with the size of the fire. This is important to remember.

In the blacksmith's forge we have a comparatively small fire consuming the fuel built up over the tuyere. The blast from the bellows or fan causes the fire to burn very brightly and fiercely. It burns so fiercely in fact that the blacksmith must be careful to build his fire so that he does not burn the metal that he is trying to heat to a welding temperature. The fire continues to burn if we turn a pail over it, but if we put a pail over an open fire it quickly goes out. The reason why the forge fire continues to burn when covered with a pail and why it burns so much hotter than the open fire on the ground, is that the air is forced through it from beneath by the bellows or fan. The open fire is supported only by the air around it. The blast fans the fire and blows air all through it. It is evident that the air supplies some element necessary for combustion. What is this element? It is the part called oxygen.

Oxygen the Supporter of Combustion

The atmosphere or air around us, is composed of about one-fifth oxygen and four-fifths nitrogen. Nitrogen is an inert gas

that does not support fire but hinders it. The oxygen in the air is the supporter of all combustion. It is the so-called life-giving element in the atmosphere that we breathe into our lungs. The oxygen enters the lungs and purifies the blood coming in from the veins, changing it from a dark, almost black, to bright red. This action is a kind of combustion in which the impurities or carbon in the blood, are burned out. The temperature of this combustion, of course, is very low, being 98.6 degrees F. in health. Rusting of iron is a slow combustion of the iron due to oxygen in the air, and moisture.

There is a limit to the temperature that can be produced in the forge. While the blacksmith is able to melt cast iron and burn steel, he cannot do much more economically. It was discovered years ago that if the air supplied to the blast is first heated, a much higher temperature can be produced. It doubtless has occurred to you that is contradictory that a blast of air makes a fire burn hotter. You know that in summer when very warm you take advantage of the blast produced by a fan to cool you off. Now as a matter of fact the blast in the blacksmith's forge which makes the fire burn hotter, also tends to make it burn cooler. How is this explained? The blast makes the fire hotter because it supplies a greater amount of oxygen, but at the same time it tends to cool the fire because a large volume of comparatively cold nitrogen is forced through the fire. Now if this nitrogen is heated to a comparatively high temperature it will not have so great a cooling effect as when introduced cold. This is taken advantage of in the open-hearth steel furnace. The open-hearth furnace is so constructed that fire-brick checker work is heated to a high temperature by the waste hot gases, and then by turning a valve or damper the cold air blast is forced through this checker work and is thereby heated to a high temperature before reaching the fire. The result is that a temperature of over 3000° F. is produced, ample for melting steel.

Conditions Required for Perfect Combustion

When coal is consumed the combustion produces invisible gases, smoke and ashes. The ashes are the mineral content of the coal that is incombustible. The smoke is unconsumed carbon

while the gases are the product of combustion and consist chiefly of carbon dioxide and water vapor, or steam. Incomplete combustion and impurities in the fuel limit the temperature that can be produced. Perfect combustion can be secured only with pure fuels and sufficient oxygen supply. In short, ideal combustion can be produced only when the fuels consists only of the necessary combustibles and oxygen, and when they are supplied in exactly the right proportions.

Hence, if we are to get perfect combustion and high temperature we must reject all solid waste matter like ashes and also all waste gases which dilute the fuel or oxygen supply, hinder combustion and carry off heat without doing good. The most efficient combustible gas we can use is acetylene. This gas is simply produced by slaking calcium carbide in water, and is carbon and hydrogen chemically combined. Both carbon and hydrogen are good fuels but when combined they make a much better fuel—one that produces an intensely white flame when burned with proper air supply, and if burned with pure oxygen the temperature produced is amazingly high, being about 6300 degrees F., or higher than any other flame known except the electric arc.

The Oxy-Acetylene Torch

We have here the oxy-acetylene torch which—as the name indicates—uses oxygen and acetylene gases.

How is it possible to produce so high a temperature in so so small a fire as the torch flame? The answer is "By getting rid of everything but that required for perfect combustion." If we could get rid of the excess nitrogen in the atmosphere, when blowing a forge fire, it is evident that the cooling effect would be greatly reduced. It is also evident that more oxygen would reach the fuel in given time. We would effect a double gain. That is exactly what is done in the oxy-acetylene apparatus. We use pure oxygen gas to combine with the combustible gas, and secure a flame the hottest part of which, not much larger than a pencil point, has a temperature that will melt the most refractory materials. The torch is capable of producing a very high temperature in a concentrated flame because the gases used are pure oxygen and acetylene. Nothing is supplied that is not re-

quired for combustion. No ashes are produced and no inert gas like nitrogen dilutes the oxygen. The oxygen and acetylene gases are supplied from separate sources through hose. The oxygen supply comes through the black hose while the acetylene or combustible is supplied through the red hose. These gases under pressure are fed to the torch through the respective hose into the handle. Just back of the handle you will find two needle valves. The valves are for controlling the flow of the gas and securing the proper proportions of oxygen and acetylene supply.

The two tubes join in the head where the gases are brought together and mixed. The amount of gas that can escape at the tip depends on the diameter of the hole. The gas flowing from the tip governs the size of the flame. If we need a small flame we must provide a small hole in the tip and if we need a large flame we must have a larger hole. This is taken care of by changing the tips to suit the work in hand. The tips are interchangeable and are easily removed and replaced by loosening a nut which holds them in place. The gases mix in the head of the tip, and each size of tip is drilled to secure the most thorough intermingling of the volume of gas it is designed to supply. The tips are numbered, the small tips having the low numbers and the large ones the high numbers. The smallest tip is No. 00 and the largest No. 12, for the Style C welding torch. The size of the tip in this torch is No. 2.

We open the oxygen cylinder valve and adjust the oxygen regulator to a pressure of four or five pounds, with the upper needle valve in the torch handle open. Then we close the oxygen needle valve in the torch and open the lower or acetylene needle valve. The acetylene regulator handle is in the closed position, being turned to the left. We open the acetylene cylinder valve and adjust the acetylene regulator to a working pressure of two pounds. The gas is now flowing from the acetylene cylinder through the red hose and escaping from the torch tip. We use the ignitor and light.

You will notice that it burns with a long smoky flame. The oxygen required to support combustion now comes from the air around it. Now open the oxygen valve, and notice an immediate change. The smoky flame has disappeared, and we have a shorter,

more fiercely burning flame, the hottest part of which is evidently at the tip. By turning the needle valve we change the appearance of the flame. When the proportion of oxygen and acetylene are exactly right for perfect combustion we have what is called the neutral flame. The neutral flame tends neither to carbonize the metal against which it is directed, nor to oxidize it. If we shut off a part of the oxygen supply you will notice that the flame then consists of a white cone, a white envelope verging into a blue as it becomes further removed from the tip. When directed against metal the free or excess carbon in the flame tends to combine with the heated metal. This is shown by a cloudy boiling in the puddle. This we call a carbonizing flame because it tends to increase the carbon content of the metal being welded. If now we increase the oxygen supply we notice that sparks fly when the flame is directed against the steel. The molten metal foams and sparks and burns. We now have an oxidizing flame—an excess of oxygen. The excess oxygen tends to burn the steel as well as the acetylene.

In adjusting your torch flame the aim should be to produce the neutral flame. You should learn to distinguish between the neutral, carbonizing, and oxidizing flames instantly. Much of the trouble experienced by oxy-acetylene welders has been due to lack of skill in adjusting their torches. Improper adjustment means the wrong flame and that means poor welding and wasted gases.

The oxy-acetylene apparatus is flexible; the flame may be directed exactly where we want it. We take the flame—our welding tool—to the work. The blacksmith must take his work to the forge and heat it all over. Then he must pound it with a hammer. No hammering is required for torch welding. The molten metals merge and become one in cooling. The forge is a crude primitive means for welding compared to the highly portable, flexible and efficient oxy-acetylene torch. It can be used only for welding iron and steel whereas the torch will weld cast iron, copper, brass, aluminum and other metals also.

Questions

1. What is the effect of an air blast on fire?
2. Why does the blacksmith's forge produce a higher temperature than can be obtained in an open fire?
3. What gas is the supporter of combustion?
4. What is welding?
5. What are the common fuels?
6. What are the conditions required for perfect combustion?
7. Is a large fire necessarily a hot fire?
8. What are the colors of the oxygen hose and the acetylene hose?
9. What do you do when you want to change the size of the torch flame?
10. Which needle valve in the torch do you open first when starting?
11. Where is the hottest part of a torch flame?
12. What kind of a flame is required for most welding?

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OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

FLAME AND ITS STRUCTURE

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

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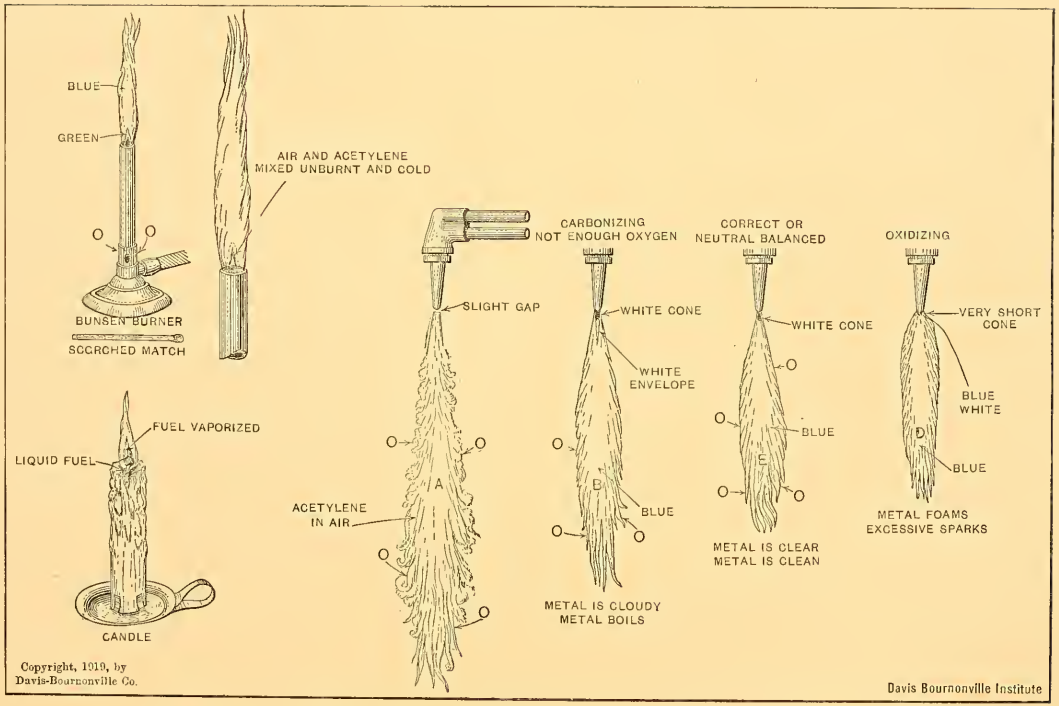

FIG. 1. CANDLE FLAME, BUNSEN FLAME AND TORCH FLAMES.

FLAME AND ITS STRUCTURE.

All Flame Combustion Gas Combustion — Structure of Candle Flame — Bunsen Gas Burner—Bunsen Burner Embodies Principles of Torch—Carbonizing, Oxidizing and Neutral Flame Characteristcs—Adjusting the Torch Flame.

Combustion is the burning of any fuel with a supply of oxygen, taken either from the atmosphere or from some other source of oxygen supply. In this lecture we will take up combustion in the typical flame. The principal combustibles are wood, charcoal, hard coal, soft coal, coke, tar, petroleum, fuel oil, kerosene, illuminating gas, hydrogen, and acetylene. You will notice that this list includes solids, liquids and gases.

All Flame Combustion Gas Combustion

All flame combustion is gas combustion, irrespective of whether the fuel is solid, liquid, or gaseous. We have here an ordinary paraffine candle. We light the wick. As soon as the wick is afire, the heat creates a pool of liquid paraffine around the base of the wick. The liquid paraffine rises in the wick by capillary action until it reaches the zone of the flame, and there it gasifies and burns the same as the gas flame from a gas tip. When coal burns in the grate, the action is somewhat different, but the result the same. The coal is composed of carbon and hydrocarbons. A fire of some easily ignited material like wood must be built first on the grate, and when the wood has become fully ignited a small amount of coal is put on at first. The temperature of the burning wood is sufficiently high to raise the small amount of coal to the igniting point. What does this mean? It means that the coal is made so hot by the burning wood that the imprisoned gases are released. The escaping gases are combustible, and they take fire and continue to burn until the coal is consumed. The gases are essentially the same as the gas that comes from a gas jet. In fact illuminating gas is manufactured by the distillation of hard coal in retorts. It is washed, purified and enriched with oil gas before being turned into the street mains. In the case

of coal the production of gas takes place without melting the combustible first, as occurs in the candle, but the chief combustible is changed to gas in both cases. All combustibles are partly or wholly gasified as they burn. It makes no difference whether they are paper, wood, oil, tallow or any other solid or liquid. The hydrocarbons contained change into the gaseous state as they burn.

Structure of Candle Flame

Now we will examine the candle flame, and note its structure. In the center we have the wick, which serves to draw the liquid paraffine from the pool beneath to the burning zone. Surrounding the wick you will note a dark shape or cone. This is the gas escaping from the wick. You don't see the gas, but your eyes see a dark space where there is no flame and no light emitted. Surrounding this dark cone is the bright envelope or flame where combustion is actually taking place. Outside this bright envelope is another cooler semi-incandescent envelope. This outer envelope has tongues, curves and waves. Its shape is ever-changing. The flame is fed by the oxygen from the atmosphere; as the air rushes in from all sides it disturbs the flame, causing it to flicker, wave, rise, fall, and perform in the characteristic manner of flames in general. Flame then is red-hot and white-hot gas and air.

The flame is more or less smoky. If we hold this plate over the flame it is immediately blackened with soot. The soot is fine carbon and is unconsumed fuel. When you see smoke issuing from a factory chimney you see finely divided carbon or unconsumed fuel floating away with the invisible gases. Thousands of tons of coal are wasted every year by imperfect combustion, always accompanied by smoke. The power house chimney that belches smoke is a nuisance to the community and a disgrace to the engineer in charge.

The hollow structure of the flame is shown by a simple experiment. We insert a match stick in the flame quickly and leave it for an instant and remove. You will notice the part of the match in the center of the flame is hardly blackened while the parts exposed to the edge of the flame are burned. This shows that the center of the flame is comparatively cool and that

the hottest part is in the bright envelope surrounding the dark center.

Bunsen Gas Burner

Here is a gas burner of the Bunsen type. It consists of a short tube mounted in a base and connected to a source of gas supply. Near the bottom of the tube is a number of holes through which air can enter and mix with the gas. Surrounding this part of the tube is a closely fitting ring, also containing holes. We can turn this ring so that it wholly or partly closes the air holes in the tube. We will turn the ring or shutter so that it shuts off all the air and then ignite the gas. The flame burns much the same as the candle flame. There is a hollow center surrounded by a bright envelope, and around this is the cooler, smoky envelope, much like that we saw in the candle flame. We place a match stick in this flame and quickly withdraw it. The center is unburned but the parts that lie in the envelope are charred. The center of this gas flame must be cool because it is composed of gas coming up through the pipe. It is not quite so plain that the same condition exists in the candle flame, but the two experiments show that what is true of one is true of the other also.

We will now turn the shutter ring in the base and admit air with the gas. Immediately the appearance of the flame changes. The dark center is diminished in size and surrounded by a green cone, while above is a blue streamer and outside that a pinkish envelope. There are three distinct flame structures visible. The cone is not so apparently hollow as before, but it still has a core of unburned gas, as may be proved by again using the match stick. The stick thrust into the flame is charred at the margins of the flame but unblackened at the core. Combustion is going on quite close to the center, however, as well as in the outer envelopes. This is shown by the fact that the stick is charred throughout a greater part of the diameter of the flame than before. The flame is much hotter in the zone of the blue cone than before.

The experiment shows that combustion in the Bunsen burner is different from that of the candle flame when the air is mixed

with the gas. Why does this make a difference? It is due to the fact that when the ring at the base is turned to admit air a combustible mixture is produced that burns more or less uniformly throughout as it issues from the pipe. The flame is not now dependent on securing a supply of oxygen from the surrounding air; it finds its oxygen already mixed with the gas supply. Combustion, therefore, takes place throughout without the flickering and curling noticed when the air, or oxygen supply, is fed to the flame from the outside.

The Bunsen burner demonstrates the advantage of mixing the combustible gas and the atmosphere in correct proportions for complete combustion before combustion takes place. It operates under a disadvantage, however, which is important to call to your attention. The air entering the holes in the base of the burner is approximately one-fifth oxygen and four-fifths nitrogen. The nitrogen is incombustible and acts simply as a dilutant. It absorbs heat from the flame and passes away greatly expanded, much hotter, but unchanged. It contributes nothing to flame temperature, but on the other hand robs the flame of heat.

Bunsen Burner Embodies Principles of Torch

The Bunsen flame is very hot, but you would not know it by the color. We can convert some of the heat into light by simply placing over it a Welsbach gas mantle. Immediately we have an intense light; the temperature of the flame raises the mantle to the incandescent point and the thorium and cerium with which it is impregnated throw off a very white light. The Bunsen burner embodies the principle of the oxy-acetylene torch. In the torch we have the tip which corresponds to the tube, and the head which corresponds to the base containing the holes and the air supply control ring or shutter. You do not see this mixing part, as it is concealed in the head. The lower tube, the one connected to the red hose, supplies the combustible gas, while the upper one, connected to the black hose, supplies the oxygen. The two gases enter the head separately. They meet in the tip head and mix and then escape at the end of the tip, where combustion takes place.

The gases supplied to the oxy-acetylene torch are commercially pure acetylene and oxygen. The use of pure oxygen greatly increases the temperature of combustion, owing to the fact that we have eliminated the inert nitrogen, which acts merely as a dilutant and robs the flame of heat in the simple Bunsen burner. The flame produced with acetylene and oxygen is so hot at the tip of the white cone that it will fuse firebrick and make it run like water. The zone of the highest temperature is in this white-hot cone, and when fusing metals it is held close to the metal but not too close for fear of introducing unburned gases into the puddle of molten metal. The most effective flame for welding is obtained only by careful adjustment of the torch needle valves, as will now be explained.

Carbonizing, Oxidizing and Neutral Flame Characteristics

When we light the torch we light the acetylene gas first. The flame that issues is long and smoky, denoting imperfect combustion. It is curly, it flickers and changes shape. Streamers shoot out from the sides. This is caused by the air rushing in from all sides to supply the oxygen that supports combustion. The oxygen is now derived from the atmosphere. The flame is hot but not so hot as it would be if it did not burn smoky. Combustion is imperfect.

Now open the oxygen needle valve and note the difference. Immediately the flame changes. The smoky condition has disappeared and a white cone of flame appears at the tip. Surrounding this white cone—not much larger than a grain of wheat—is an envelope of cooler flame. You will notice in the center of the white cone, a darker cone denoting the gas issuing from the tip. It is comparatively cool. The hottest part of the flame is at the point of the white incandescent cone. It is very important that you get this clearly in mind, as success or failure in welding depends on the application of the flame correctly to the part that is to be welded.

It is evident that we can change the character of the flame by opening or shutting these needle valves. If we open the acetylene valve and close the oxygen valve the flame burns

smoky, and the hot cone or flame of greater intensity disappears. As we open the oxygen valve the intense flame increases until it reaches a maximum. Finally as we open the oxygen valve wider, we note a difference in the flame—it roars and burns more spitefully. Too much oxygen now is supplied for perfect combustion.

Let us try the effect of the different flames on a piece of steel. We will first start with an excess of fuel, that is the acetylene supply will be in excess of the oxygen supply. When this flame is directed against the metal it becomes red, then white hot, and then the metal melts and begins to boil. What does this boiling indicate? It shows that the flame contains excess fuel or carbon. The carbon is mixing or uniting with the steel as it melts. The steel is carbonizing, and it will be brittle when cold. A flame that causes the steel to boil and become cloudy is a carbonizing flame. The resulting weld will be pitted and brittle. The carbonizing flame must be carefully avoided when welding steel, if you wish to produce sound strong welds. A slightly carbonizing flame is recommended for welding aluminum.

Now turn on the oxygen by opening the oxygen needle valve further. Adjust the valve so that the carbonizing flame envelope just disappears, and no further. The flame now burns clean. The white hot cone at the tip is well defined. When we apply to it the steel, the metal becomes white hot and melts, but it lies quiet under the flame. It neither boils nor sparks. This is the neutral flame, and is the flame that you should always try to get when welding steel It should be remembered that the so-called neutral flame has the neutral characteristic only when properly applied to the metal. If held too close the unburned gas in the core may penetrate the molten metal and result in producing occlusion, blowholes and other defects.

Note the difference when we open the oxygen valve still further. The white cone, or section of intense heat, becomes very short, and blue-white. Outside is a long blue envelope. The flame roars and sounds spiteful. When this flame is directed against the steel and it reaches the melting temperature the metal foams and sparks. This action shows that excessive oxygen is

being supplied and that the oxygen is combining with the steel and burning it. The oxidizing flame is as fatal to success in welding as is the carbonizing flame, and must always be avoided. It is shown by foaming and sparking. The resulting weld is shiny and weak.

You now have seen the three conditions of flame; at the one extreme is the smoky carbonizing flame, due to excess fuel; at the other is the sparking blue flame, due to excess oxygen; and between is the steady flame of greatest intensity. The molten metal lies in a clear, clean pool or puddle beneath this flame. It tends neither to become cloudy and boil nor to foam and spark. You will fail as a welder if you do not become proficient in adjusting the flame to secure neutral or balanced combustion. Balanced combustion is desirable not only because it produces the best welds, but because it makes for economy of gas consumption. When you burn a carbonizing flame you are wasting acetylene; and when you burn an oxidizing flame you are wasting oxygen. It is only when you have the perfectly balanced flame that you are burning both gases economically. So, from every point of view it is necessary to adjust the flow of gases carefully and secure the neutral flame to get the best results.

Adjusting the Torch Flame

Four distinct flames can be produced with the oxy-acetylene torch, but three, only, produce sufficient heat for welding iron and steel. A in Fig. 1 shows the pure acetylene flame. The gas is burning with no oxygen supply except that which comes to it from the atmosphere. A short gap appears between the tip and the flame. B shows the carbonizing flame. The acetylene is burning with partial but insufficient oxygen supply. E shows the balanced or neutral flame. This is the correct flame to use. The oxygen and acetylene are supplied in exactly the right proportions for efficient combustion. D is the oxidizing flame. More oxygen is being supplied than required for the burning of acetylene.

Carbonizing Flame Characteristics

Combustion is unbalanced; there is insufficient oxygen and excess carbon in the flame. A white cone appears at the tip, and

beyond the flame there is a white envelope of cooler flame. The streamer is a long blue flame.

Effect of Carbonizing Flame.—The excess carbon tends to enter and combine with the molten metal. The metal boils and has a cloudy appearance. The surface of the weld when cool is mottled or pitted in appearance. The weld is brittle.

Neutral Flame Characteristics

Combustion in the flame is balanced, and two distinct cones are visible. The cone next to the tip is white hot, and beyond it is a long blue streamer, also very hot. The sound of the neutral flame differs from that of the carbonizing flame.

Effect of Neutral Flame.—The molten metal lies quiet beneath the flame. It is clean and clear. It flows like syrup, and few sparks are produced. The weld made with the neutral flame will be free of carbonized and oxidized metal.

Oxidizing Flame Characteristics

Combustion is unbalanced because of excess of oxygen. The oxygen combines with all the fuel or acetylene available, and the remainder tends to attack the metal. The white cone is very short and is surrounded by a blue white envelope. The streamer of the flame is blue.

Effect of Oxidizing Flame.—The metal sparks, and a white foam forms on the surface of the puddle, denoting oxidation. The cold weld is shiny and has little strength. It contains oxidized metal.

Summary

The carbonizing flame is caused by excess acetylene gas; its effect is to make a brittle weld. The oxidizing flame is caused by excess oxygen; and its effect is to make a shiny weld of little strength. The neutral flame is produced by balancing the oxygen and gas supply so that perfect combustion is secured. Excess of either gas is harmful and wasteful. The welds produced with the neutral flame are sound and free from oxide and excess carbon.

Questions

1. In what way do you determine the neutral or balanced flame?
2. Why does the combustion of oxygen and acetylene produce so hot a flame?
3. Which is the combustible gas?
4. What part does oxygen play?
5. What is the appearance of an oxidizing flame?
6. What is the appearance of a carbonizing flame?
7. How do you know when you have the neutral or balanced flame?
8. What is the appearance of a weld made with a carbonizing flame?
9. What is the appearance of a weld made with an oxidizing flame?
10. What part of the flame is the hottest?
11. How close should the flame be held to the metal?
12. Why should care be taken not to touch the metal with the white hot cone?

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DAVIS-BOURNONVILLE
OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

REGULATING THE GAS SUPPLY

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

Form 377

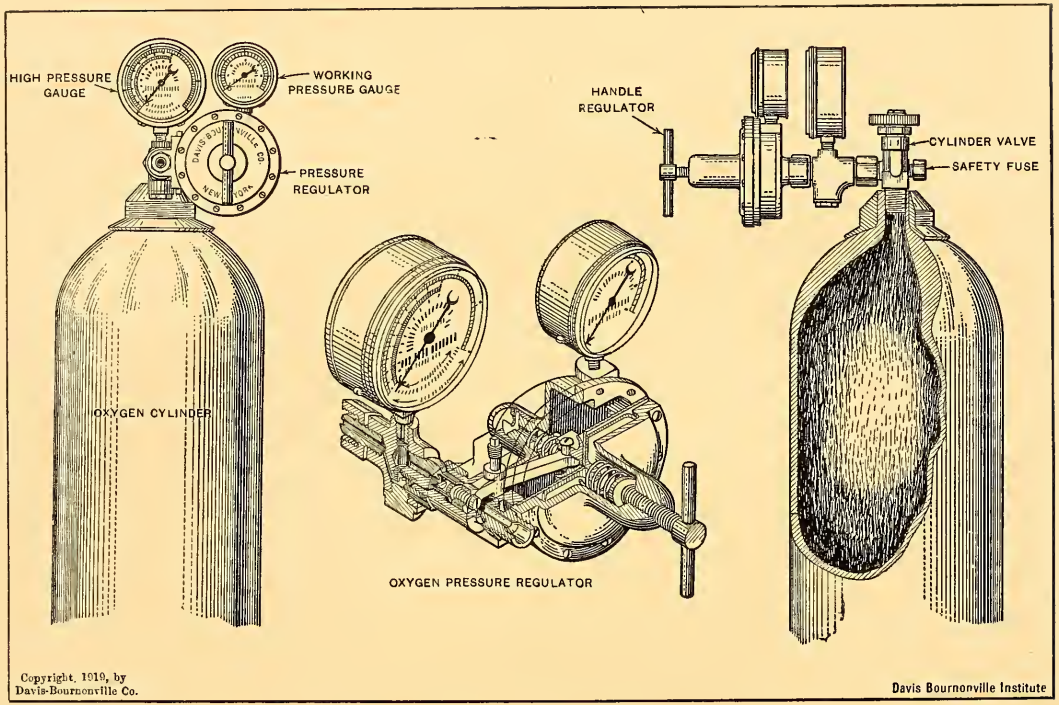

FIG. 1. OXYGEN PRESSURE REGULATOR OF THE INDIRECT ACTING TYPE, AND OXYGEN CYLINDERS.

REGULATING THE GAS SUPPLY

All Gases Compressible—Pressure Reducers or Regulators—To Regulate Working Pressure—Principle of Pressure Gauge Operation—Danger of Testing Oxygen Gauges with Oil—Pressure Reducers or Regulators—Principle of Pressure Regulator Action—Direct Acting Pressure Regulator—Line Pressure Regulator of the Indirect-Acting Type—Care of Regulators—Action of Pressure Regulators Reviewed.

In the previous lecture we talked about combustion and the structure of flame. Today we will take up the matter of controlling the flow of the oxygen and acetylene gas to the torch. The flow of gas through a pipe depends on the diameter of the pipe and the pressure behind it. If you need little gas a small pipe and low pressure will supply it, but if you need much gas for a large flame a larger aperture and greater pressure will be required. The control of the torch flame then is accomplished by regulating the size of the orifice through which it escapes to the atmosphere and the pressure of the respective gases. This talk will be on regulating the gas pressures.

All Gases Compressible

You have noticed, of course, that the hose are connected to two pipe-lines or sources of supply. In the field your sources of gas supply will be usually two cylinders like these; one of the cylinders contains the fuel supply or acetylene gas, and the other the oxygen. The gases in the cylinders are condensed under heavy pressure. All gases are compressible, which means, for instance, that a gallon of gas may be squeezed into a half-gallon can if sufficient pressure is applied. There is, in fact, hardly any limit to the compressibility of gases in general. Gas is quite different from water in this respect. A gallon of water is a gallon—no more and no less. Practically you cannot squeeze it into much less space, no matter how great the pressure applied. A pressure of 3000 pounds to the square inch will compress water only one per cent. A pressure of 3000 pounds to the square inch will compressure gas into less than one-two hundreth of its free bulk. The oxygen cylinder contains the gas under a pressure of about

1800 to 2000 pounds to the square inch, while the acetylene cylinder contains this gas under a pressure of about 225 pounds to 275 pounds to the square inch. These pressures are the maximum, and they decrease as the gases are used.

Pressure Reducers or Regulators

You will notice on the oxygen cylinder two gauges, and below one of the gauges a device called the gas pressure regulator. This gauge, which registers up to 3000 pounds per square inch, shows the pressure of oxygen in the cylinder when the stop

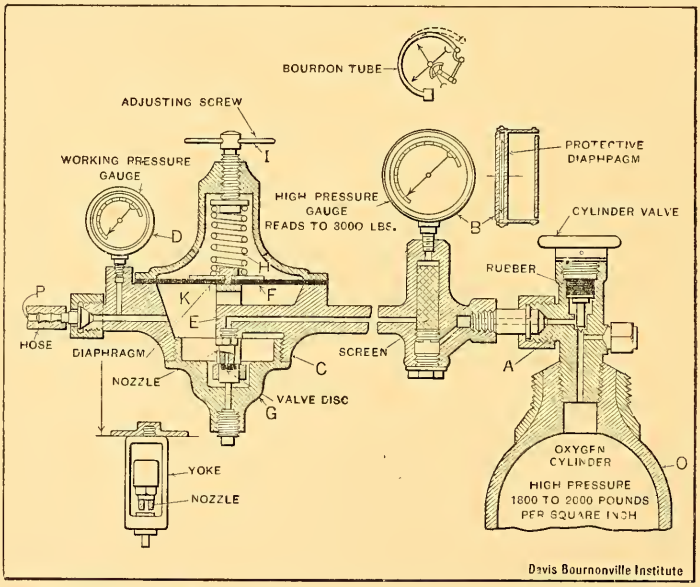

FIG. 2. DIAGRAM SHOWING PRINCIPLE OF SIMPLE PRESSURE REGULATOR, AND PRESSURE GAUGE.

valve is open. We cannot use a pressure of 1800 pounds to the square inch in the torch; it is entirely too high, and must be reduced to a comparatively low working pressure. The working pressure depends on the aperture in the tip, which in turn governs the size of the flame. For welding metals up to 3/8 inch thick the acetylene working pressure is the same as the number of the tip and two times the number of the tip for the oxygen.

For instance, if a No. 2 tip is being used we should adjust for a working pressure of two pounds acetylene and four pounds oxygen per square inch. To regulate the gas supply proceed as follows, first making sure that the regulator handles are in the closed position:

To Regulate Working Pressure

Open the valve on the oxygen cylinder as far as it will go, and admit the gas to the pressure regulator. This stop valve must be opened very slowly as you are dealing with a very heavy pressure, which will surely damage the apparatus if not handled carefully. The valve must be opened wide in order to prevent leakage around the stem. You will note that as the gas was admitted the hand on the gauge has moved from the zero point. It now indicates about 1800 pounds pressure. Having turned on the oxygen we are ready to adjust the working pressure by means of the pressure regulator. To do this open the oxygen needle valve in the torch and turn the regulator valve handle slowly to the right. At first it moves easily and then it begins to offer some resistance. When you feel the resistance increasing, turn the handle slowly. Now the gas is escaping through the hose. The hand of the working gauge begins to move over the graduated dial, and when it reaches 4 stop opening the regulator valve. The flow of gas has been adjusted for a working pressure of four pounds per square inch, which is about right for the No. 2 tip when the gas supply is constant. If, however, the supply is taken from a cylinder it is customary to adjust for slightly higher working pressures in order to compensate for falling pressure as the gas is used up.

Now close the oxygen needle valve in the torch, and open the acetylene needle valve. Open the stop valve on the acetylene cylinder also very slowly. The pressure on the gauge rises to about 225 pounds per square inch. Having admitted the acetylene to its pressure regulator we are ready to regulate the working pressure of the fuel supply. Turn the regulator handle to the right slowly as before, until it meets increasing resistance, and then turn very slowly. As the valve opens and admits the acetylene gas the hand of the acetylene gauge begins to move

over the graduated dial and when it indicates 2, or slightly more, stop opening the regulator. Close the acetylene needle valve if not ready to immediately ignite the flame. As a rule you should be ready to start using the torch, but we will close the acetylene valve for the moment, and describe the construction of the gauges and the regulators. It is important that you understand the principles of these parts of the apparatus, as your success as a welder and your personal safety depend on the care you give them.

Principle of Pressure Gauge Operation

Here is a pressure gauge that has been partly dismantled to show the construction. You notice in the center, a curved flat tube, one end of which is attached to the gauge stem, while the other or closed end is connected by means of a lever and a short curved rack to a small pinion.

We will mount this gauge on the cylinder and open the valve. The tube tends to straighten when the pressure is admitted, but the movement is too small to be seen. It is known as a Bourdon tube, and is the pressure part generally used in gauges. A tube like this tends to straighten when subjected to internal pressure, because the flattened cross section tends to become circular. This has the same effect as increasing the inner circumference and shortening the outer. The movement of the end of the tube is so slight that it is necessary to multiply it in order to see the movement of the hand on the dial. This multiplication of movement is accomplished by the lever connection and the curved rack and pinion. The pinion is mounted on the spindle that carries the indicator hand. A very small movement of the tube will turn the hand completely around the dial. Beside the pinion is a hairspring; one end is attached to the body and the other to the spindle. This hairspring offers a slight resistance to the movement of the Bourdon tube, and it returns the hand to the zero point when the pressure is released.

The movement of the hand over the graduations of the dial is calibrated or compared with a master gauge to make sure that the indications represent correctly the pressure in pounds per square inch. The term "pounds per square inch" means that

every square inch in the cylinder shell supports a load, pressure, or weight, and a gauge pressure is a device for weighing the pressure. If the internal area of the shell of an oxygen cylinder, for instance, is 100 square inches, it sustains a load of 180,000 pounds when the pressure is 1800 pounds to the square inch.

The outer graduations on the high pressure oxygen cylinder gauge dial read "Pounds per Square Inch in the Cylinder;" the

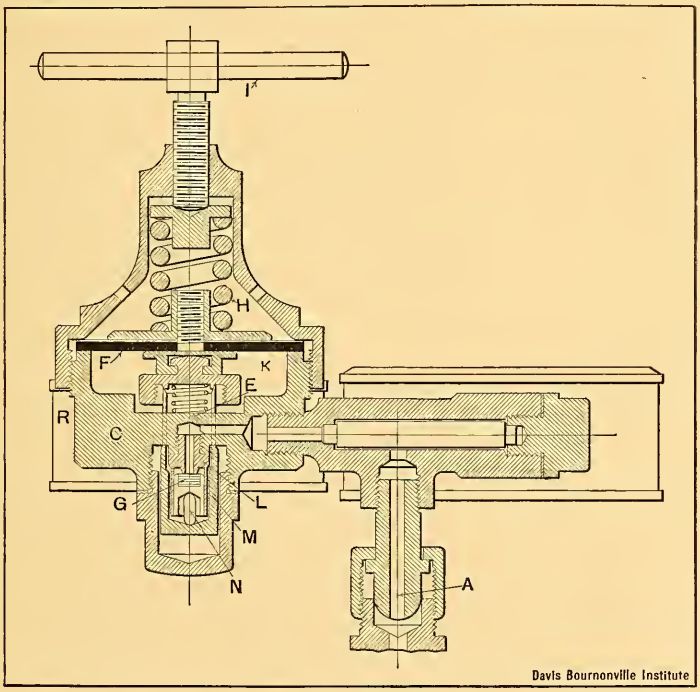

FIG. 3. DAVIS-BOURNONVILLE NO. 2 HIGH-PRESSURE OXYGEN REGULATOR.

graduations of the next circle read "Number of Cubic Feet in a 100-Foot Cylinder;" and the inner circle of graduations "Number of Cubic Feet in a 250-Foot Cylinder." Thus, you can tell at a glance both the pressure and the cubic feet remaining in a 100-foot or 250-foot cylinder. If you have a 200-foot cylinder you simply double the reading for a corresponding pressure in a 100-foot cylinder.

The front of the gauge is covered with thick glass. This glass is to protect the hand and the dial from mechanical injury and corrosion. A metal diaphragm is provided between the dial and the works, and the back of the gauge is loosely fastened in. The reason for this construction is that we are dealing with very heavy pressures and a delicate apparatus. The Bourdon tube must necessarily be made of thin metal in order to be flexible. Sometimes the metal in the tube cracks. If this should happen the oxygen gas at a pressure of perhaps 1800 pounds to the square inch would escape into the gauge case, and explode it. If the back was firmly fastened and no diaphragm was provided, the front or glass part would be blown out, the flying splinters of the glass might seriously cut anyone standing nearby or destroy the sight of the eyes. It is better then to let the back blow out in case of accident, as this being metal will not shatter. When the back is blown out the pressure is relieved and there is no danger then of the glass breaking. The safest position to take when opening a cylinder stop valve is in front of the dial.

Danger of Testing Oxygen Gauges with Oil

In the early days of the industry it was quite a common experience to have the high-pressure gauge upon the oxygen regulator explode. Sometimes the operator was not injured and sometimes he was badly hurt. Usually the reason for gauge explosions was the fact that users did not understand that oil and oxygen might cause trouble and the gauges were tested upon an oil gauge testing machine, which was a common piece of apparatus in the ordinary shop. The Bourdon tube of the gauge was filled with oil during the test, and then the gauge was directly screwed into the regulator without removing the oil. Nowadays oil is not used in testing gauges because practically all gauge manufacturers appreciate the risk run in so doing. The best practice is always to test the gauge with water and never with oil.

The same remarks do not apply to acetylene or hydrogen gauges and regulators because acetylene and oil or hydrogen and oil do not form an explosive mixture, but it is good practice to avoid the use of oil in connection with all regulators, cylinder

valves, etc. Someone who does not know the difference may see oil upon an acetylene regulator and believe that it would work equally well in connection with oxygen.

The principle of the low pressure working gauge is practically the same as that of the high pressure gauge, but as it is intended for lower pressure, it is not so strongly made. No diaphragm is provided and no provision is made for letting the back blow out, as these precautions are unnecessary.

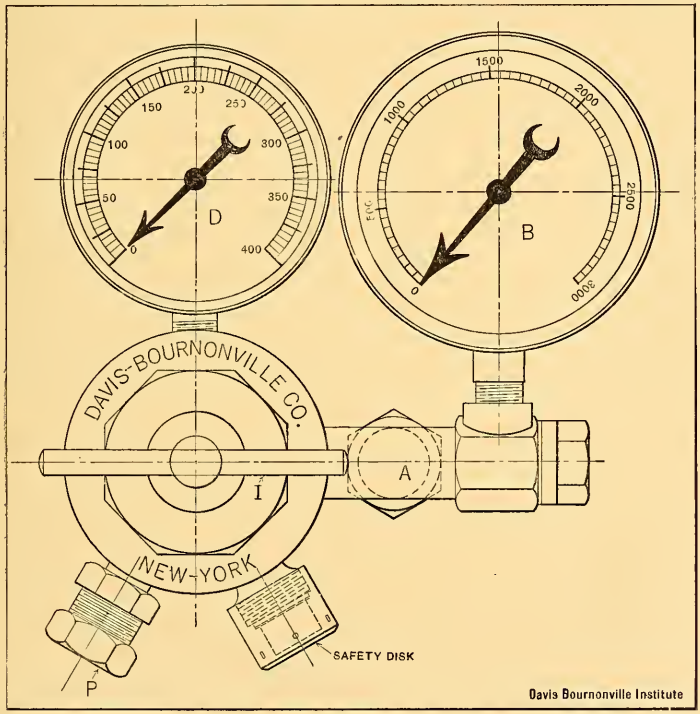

FIG. 4. HIGH PRESSURE AND WORKING PRESSURE GAUGES AND PRESSURE REGULATOR FOR OXYGEN CYLINDER.

Pressure Reducers or Regulators

We will now give attention to the gas pressure regulator. This is a highly sensitive apparatus that has required, perhaps, as much thought to perfect its design as any other part of gas welding equipment. The design of the regulator is important because it

should function properly at all times and under widely varying conditions. If the regulator does not regulate you might as well give up trying to weld because perfect regulation is absolutely necessary for success. Choose your regulator with understanding of its function, design and construction. Take the best care of it possible but, remember, that like all sensitive apparatus it may get out of order and require readjustment with even the best of care.

You can regulate pressure in a steam radiator by opening the valve a little way when you do not want the full pressure. The steam in a radiator condenses as fast as it enters, and the pressure remains nearly constant. But if you undertook to regulate the pressure in an air container in the same manner by opening a compressed air valve connected to it a fraction of a turn, you would not be successful. The pressure would "build up" in the container and soon reach the same figure as in the source of supply. It is necessary, then, to provide an apparatus that definitely measures off a certain flow of gas and checks the flow as soon as the pressure on the low side has reached a predetermined figure no matter what it may be. The gas regulator does this automatically when properly made and adjusted.

Principle of Pressure Regulator Action

The diagram, Fig. 1, is intended merely to show the principle of operation of the primitive or simple form of pressure regulator. It is not the regulator that you use, but its general principles are the same. The diagram shows the connection of the regulator to the high pressure oxygen supply. At A is the cylinder stop valve and at B the cylinder pressure gauge, at C the regulator and at D the working pressure gauge. The high pressure oxygen cylinder is at 0. The pressure in this tank when received from the manufacturer is about 1800 to 2000 pounds, and it must be reduced to a working pressure of say ten pounds to be used in the torch.

The regulator case is in two parts, and between them is a thin metal or rubber diaphragm F. Connected to the diaphragm beneath is a stirrup-shaped part or yoke terminating in a flat valve, disc G. This covers the opening in the high pressure

oxygen supply nozzle. Above the diaphragm is a coil spring, H, seated between the diaphragm and end of the regulator screw, I.

The diaphragm normally holds the valve disc, G, up against the nozzle, and shuts off the oxygen from entering the lower chamber. But when you adjust the gas regulator to get the desired working pressure you screw I to the right, thereby compressing the spring H and pushing down the diaphragm. This forces the valve away from its seat and permits the high pressure oxygen to enter the chamber and escape through the hose to the torch. When the oxygen at high pressure enters the lower chamber, it exerts pressure on the lower side of the diaphragm and tends to close the valve and shut itself off. The operation of setting the regulator is one of compressing the coil spring until it balances the working pressure desired. Your guide is the working pressure gauge D, mounted on the outlet to the torch. The diagram should serve only to give you an idea of the principle of regulator operation. Do not imagine that it truly represents the actual construction of an up-to-date and reliable gas regulator.

There are several types of regulators all operating upon the same general principle but differing in design. These types may be classed as direct-acting and indirect-acting regulators.

Direct Acting Pressure Regulator

An example of the direct-acting gas regulator is the Davis-Bournonville No. 2 high pressure oxygen regulator shown in Fig. 2. The construction and operation are quite similar to that of the diagrammatic form shown in Fig. 1. Gas under high pressure enters through the inlet A to E, where the gas passage turns downward and terminates in a screwed nozzle, L. Straddling E and the nozzle is a bronze loop or stirrup, M, attached at the upper end by a hook to the diaphragm F, and carrying below the valve disc G. The disc is held in a pocket in the bottom of the stirrup, and is supported by the pivot pin N.

The diaphragm H when not forced down by the coil spring I tends to pull the stirrup or yoke up and holds the valve disc tightly against the flat end of the nozzle L. When the valve disc is against its seat no gas can pass from A into the chamber K through the nozzle L. To permit the gas to flow the screw I

is turned to the right, thus compressing the coil spring H, which in turn forces the diaphragm down and unseats the valve disc. The gas then escapes into chamber K and thence to the outlet P, Fig. 3. This direct-acting regulator provides an auxiliary spring R beneath the stirrup to hold it aganist the seat when the diaphragm is relaxed.

The gas in chamber K presses upward on the diaphragm and counterbalances the pressure of the coil spring H. The adjustment of the regulator then is a matter of compressing the spring by the screw until its pressure is approximately equal to the pressure of the gas in pounds per square inch multiplied by the area of the diaphragm in square inches.

Line Pressure Regulator of the Indirect-Acting Type

Fig. 3 shows the Davis-Bournonville acetylene pressure regulator of the indirect or lever type for regulating the pressure in supply lines. The lever connection between the diaphragm and the inlet valve is so proportioned that the diaphragm end moves about three times as far as the short end controlling the movement of the valve. Thus a movement of the diaphragm center of say one-hundreth inch is reproduced at the gas valve by a movement of only about one three-hundreth inch. The design thus provides a reducing movement by which the opening of the gas valve may be controlled with very small variations. The regulator shown is for operating under the low pressure of 15 pounds per square inch and reducing it to the torch working pressure. The same general design is also provided for oxygen pipe line pressure control.

The inlet A is connected to the pipe line, and the gas passes through a screen or strainer and beneath the valve disc G into the cavity K, where it exerts pressure on the diaphragm F, as in all the other types of pressure regulators. The outlet P to the torch is in direct line with the inlet passage.

Pressure regulation is effected by means of the regulator handle I and the compression spring H, which must be adjusted so that the pressure of the spring on top of the diaphragm counterbalances the gas pressure beneath and also the pressure exerted by the auxiliary regulator spring Q seated on the

auxiliary diaphragm S. Beneath this diaphragm is a space connected by a passage to the gas supply pipe. The coil spring T beneath the diaphragm is provided to balance the pressure of spring Q and relieve the diaphragm S. The function of the

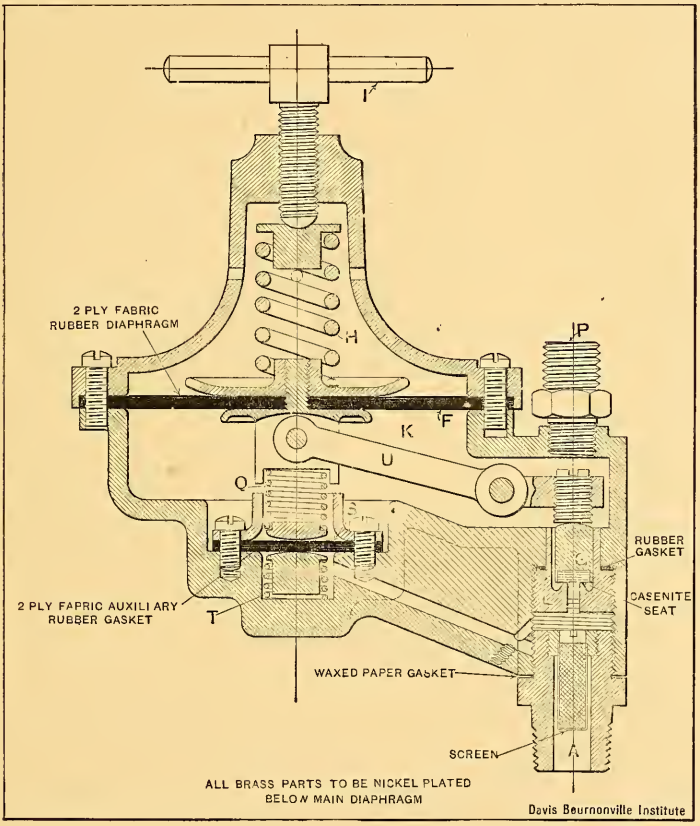

FIG. 5. DAVIS-BOURNONVILLE LOW PRESSURE ACETYLENE PRESSURE REGULATOR

supplementary diaphragm is two-fold: It increases the sensitiveness of regulator action on a pipe line distributing system by acting on the valve control level direct. Fluctuations of pressure are in a sense anticipated and provided for before the change of pressure has affected the pressure in the chamber beneath the main diaphragm. It also provides for automatically

shutting off the flow of gas in case the diaphragm is burst by over-pressure. The escape of gas from the chamber K through rupture of the diaphragm permits the gas beneath the supplementary diaphragm and the spring pressure to act on the reducing lever U in opposition to the pressure of spring H and close the valve G firmly upon its seat. The oxygen regulator of the same type is provided with a bursting disc beneath the supplementary diaphragm to prevent the building up of dangerous pressures in the line.

Care of Regulators

The gas passes through the screen chamber of the regulator and is strained by a fine mesh screen before coming in contact with the seat. The seat must be tight or the regulator will give all sorts of trouble. A small particle of scale, grit or dirt lodging under the seat will of course make it leak. It can be readily appreciated that the regulator will not give close regulation and may in fact become very troublesome if its use is continued with a leaky seat. The pressure upon the diaphragm in that event does not shut off the nozzle completely and the gas continues to flow into the regulator causing the pressure within the low the flow into the regulator causing the pressure within the low pressure chamber of the regulator to climb or build. This is indicated by the small gauge.

The pressure creeps higher and higher when the torch is shut off until finally the small gauge is broken or the safety disc in the back of the regulator bursts. This safety disc is a simple disc held in position over an outlet of predetermined size by a nut. The thickness of the disc and the size of the outlet determines the pressure at which it will burst. This pressure is usually somewhat greater than the maximum working pressure of the regulator. It will be appreciated, however, that there is a good deal of variance in the pressure at which the disc will burst even with discs of the same thickness and outlets of the same diameter; hence, the function of the bursting disc is largely to prevent excessive pressure remaining long within the regulator casing. The disc will burst long before the casings are blown apart but not always before serious damage is done to the gauge.

If a regulator leaks, stop using it and see that it is properly repaired before attempting to operate it again. It is not difficult to repair the regulator; as a rule, it is only necessary to renew the seat and consequently a few extra seats should always be available. It is always good practice to maintain a few extra bursting discs so that in case one bursts a new one can be inserted. It should be borne in mind, however, that if the safety disc bursts, you should always test the seat to determine that it is tight before putting a new disc in place. A bursting disc is almost always an indication of trouble elsewhere in the regulator.

In setting up the joint in the regulator, a little shellac is usually the best material to use. Do not use paint, white lead or oil. High pressure oxygen and oil or any other inflammable material are likely to cause an explosion under certain conditions if confined together. A word should here be said in this connection about the use of a suitable lubricant upon the adjusting screw of the regulator. The regulating screw of the regulator does not come in contact with oxygen or the gas within the regulator as the gas does not pass the diaphragm. There is then no reason why a suitable lubricant should not be used upon this screw. Care should be taken, however, that this lubricant is not allowed to get into the regulator; it is best in such instances to use tallow or graphite and not oil.

Action of Pressure Regulators Reviewed

Now to review the action of a gas pressure regulator. When the cylinder valve is opened, gas is admitted to the chamber communicating with the high pressure gauge but it can go no further so long as the pressure regulator handle I is in the released position. But when you turn the regulator handle to the right or in a clockwise direction it screws in and compresses the coil spring directly beyond it. The pressure of the spring is transmitted to the diaphragm and the resulting movements communicated to the valve stirrup or connecting lever, (depending on the type of regulator) opens the gas valve and lets the gas escape into the chamber beneath the diaphragm. The pressure immediately overcomes the pressure of the spring, and

more clockwise movement of the regulator handle is required to compress the spring still further in order to counterbalance the gas pressure. Finally you secure the adjustment required. By the process of adjustment you produce a state of balance between the pressure of the coil spring on top of the diaphragm and the gas beneath it. As soon as the conditions one way or another change, the diaphragm rises or falls and the rate of flow of the gas escaping from the cylinder is changed.

Obviously, you cannot adjust a pressure regulator correctly unless the needle valve in the torch is open. If you want the working gauge hand to stand at 8 pounds pressure when the torch is in use the needle valve must be opened while you adjust the regulator handle until the hand shows 8 pounds pressure. If you undertook to adjust the regulator with the needle valve closed the chamber beneath the diaphragm would quickly fill and the working pressure indicated would not be maintained when using the torch. The moment you opened the needle valve it would probably fall below the working pressure desired, and thus make necessary readjustment of the regulator valve handle.

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OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

THE OXY-ACETYLENE TORCH

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

Form 378

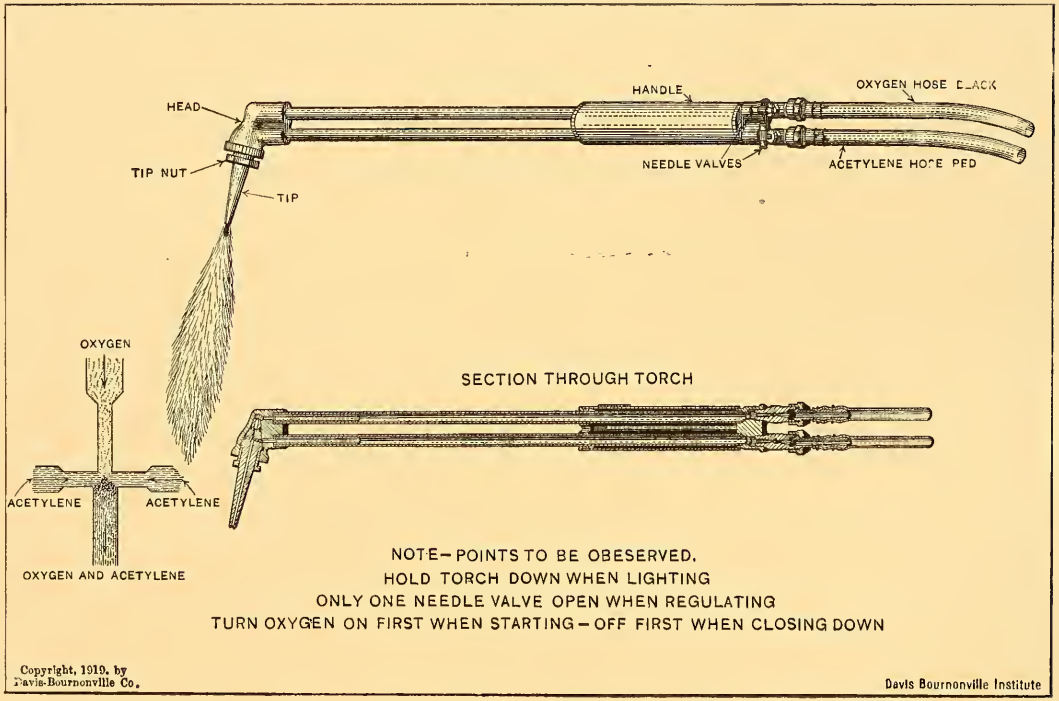

FIG. 1.—THE OXY-ACETYLENE WELDING TORCH SECTIONS SHOW TORCH CONSTRUCTION AND ILLUSTRATE THEORY OF GAS MIXING.

THE OXY-ACETYLENE TORCH

The Simple Blowpipe—The Bunsen Burner—The Bunsen Type Blow Torch—The Injector Type Blowpipe—Acetylene Commercial Development—Oxygen Commercial Development—Davis-Bournonville Oxy-Acetylene Welding Torch—The Interchangeable Tip System—The Mixing Head or Carburetor—Gas Pressures for Welding—Care of Torch and Tips.

The hand oxy-acetylene torch in general use today for welding is a tool or apparatus for mixing a combustible gas with

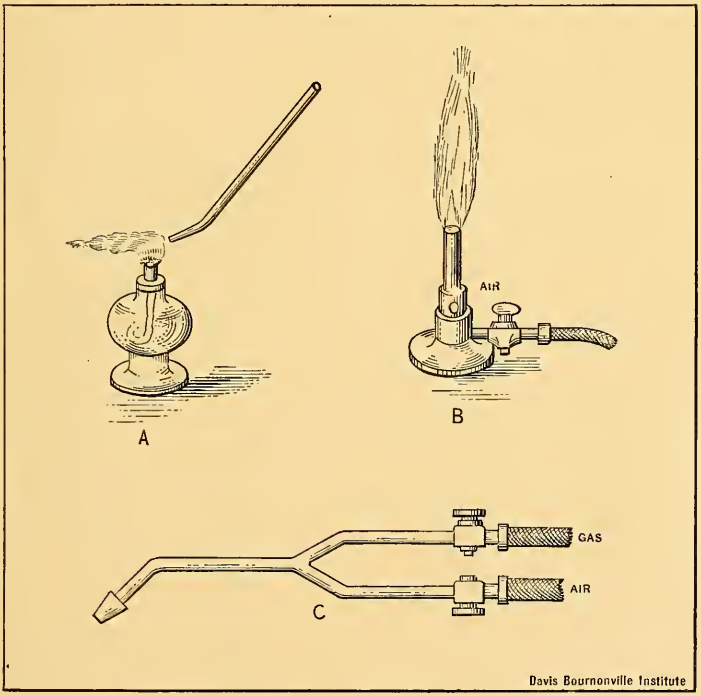

FIG. 2.—THE SIMPLE ALCOHOL FLAME BLOWPIPE, THE SIMPLE BUNSEN BURNER AND THE SIMPLE BUNSEN BLOWTORCH.

oxygen in certain definite proportions, burning the resulting mixture and directing the intensely hot flame upon the parts to be welded.

The Simple Blowpipe

The gas welding torch is a comparatively recent development of the simple blowpipe that you have often seen used, no doubt, by jewelers and watch-makers. Blow-pipes have been used from time immemorial by the workers of gold, silver and brass to melt their solders and brazes. The ordinary blow-pipe is a simple tube curved at the tip through which the workman blows against the flame to increase its intensity. It is generally used with an alcohol lamp both to increase the heat of the flame and to direct the flame point where it is required to heat. A skillful workman can direct the flame with great precision, and make it melt any of the hard solders.

The blow-pipe probably antedates the blacksmith's forge. It corresponds to the bellows and is a much simpler means of producing a blast of air. The first blow-pipe, no doubt, was a hollow reed that some primeval man used with astonishing effect on a fire and the bits of virgin metal that he had collected.

The Bunsen Burner

Following long after the blow-pipe came the Bunsen burner or gas torch. This, like some other very valuable devices, had its origin in the laboratory. The Bunsen burner differs from the blow-pipe in that the air required to increase the intensity of combustion is so applied that it mixes with the gas before it reaches the zone of combustion. The air is introduced through a tube at the base of the burner where it mixes with the combustible gas, and the mixture burns at the mouth of the tube with an intense blue flame.

The temperature of the flame in the simple Bunsen burner depends on the gases used and their pressure. The proper mixture of air and gas is obtained by adjusting the ring at the base which acts like a stove damper. When the ring is set so that the openings in the ring and tube coincide the maximum amount of air is admitted. Bunsen burners of the simple air induction type are generally made so that an excess of air is admitted when the ring is adjusted for the full opening.

The Bunsen Type Blow-Torch

The Bunsen burner we have here is a laboratory apparatus of the simple so-called air induction form to demonstrate the principles of combustion. It differs from the commercial Bunsen burner considerably. Brazing burners or torches are generally made so that they may be conveniently handled and usually the air is supplied through a separate hose under some pressure. The Bunsen burner referred to consists of two brass tubes united by a cross tube set at a convenient angle, and terminating in a nozzle. At the rear are two stop valves by which the workman can adjust the flow of air and gas and secure the size of flame desired. It is a very simple apparatus,

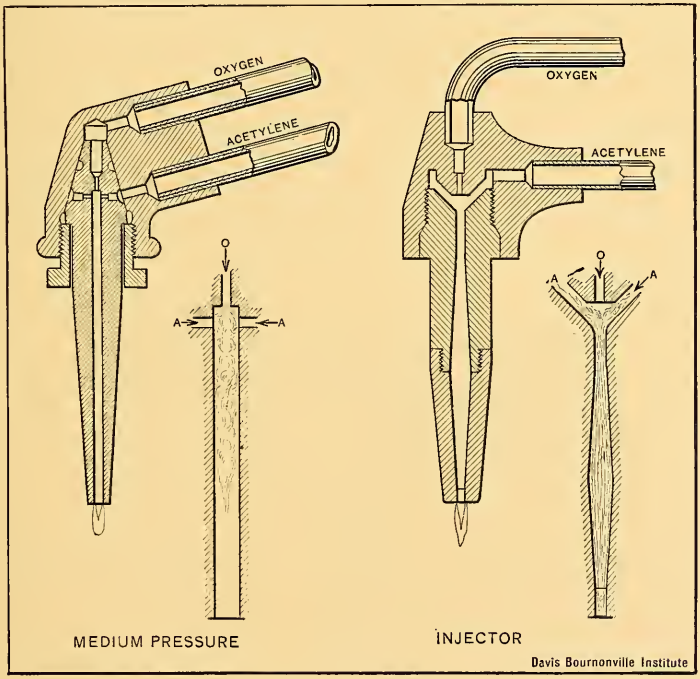

FIG. 3.—SECTIONS OF POSITIVE PRESSURE AND INJECTOR TYPE TORCH HEADS.

and is much used for heating, soldering, sweating, brazing, lead burning and other purposes where it is necessary to apply heat

locally. When used for lead burning, the Bunsen burner is supplied with pure hydrogen gas and compressed air. In the hands of a skilled lead burner it becomes a most effective tool for uniting the lead sheets of acid tanks. This work, by the way, is a form of so-called autogenous welding that has been long in use but which is well known to but comparatively few.

It is rather curious to find that all the elements apparently of the modern gas torch were in use years ago; why then has it remained for the extraordinary development of the oxy-acetylene torch to take place in the past fifteen years? The answer is acetylene and oxygen.

Acetylene Commercial Development

The discovery of a commercial method of making calcium carbide and producing acetylene by Thomas L. Willson in 1892 gave the world a new combustible of extraordinary characteristics and value. The commercial possibilities of acetylene made by slacking calcium carbide were early recognized in the lighting field but its value as a gas for producing intense combustion was not recognized so soon and it was nine years

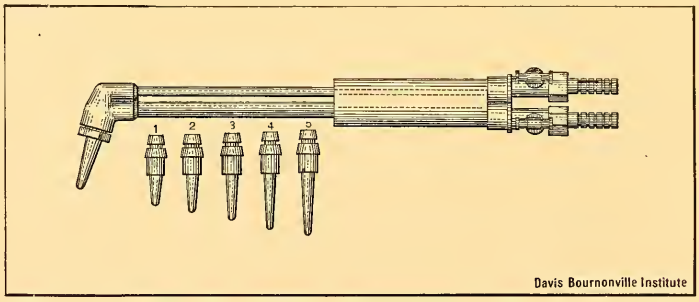

FIG. 4.—SMALL STYLE C WELDING TORCH WITH REMOVABLE INTERCHANGEABLE TIPS.

later before the first practical oxy-acetylene welding torch was developed by Edmund Fouché of Paris in 1901.

The oxy-acetylene torch is another example of valuable commercial apparatus that has been made possible by different researches and discoveries seemingly far apart but which later

were combined with astonishing success. It had long been known that pure hydrogen and pure oxygen burned in the Bunsen burner in the proportions of two parts of hydrogen to one of oxygen produced an intensly hot flame. The temperature produced by the oxy-hydrogen flame is 4000 degrees F. It was for many years the source of the greatest flame intensity within the reach of the chemist and physicist.

The first oxy-acetylene torches made by Fouché were very crude affairs compared with the modern welding torch equipped with its interchangeable tips and efficient gas regulating system. Simple and crude as it was it represented tremendous steps in the advancement of science. Beginning with the blow-pipe as a means of increasing the intensity of flame the next step was the simple Bunsen burner, burning hydrogen and air. The next step of refinement was the burning of hydrogen and pure oxygen. This step was a very important one as a supply of pure oxygen will greatly increase the intensity of any flame. But the next step in the development of the oxy-acetylene torch could not be taken as acetylene gas was not available. But, when Willson discovered acetylene,

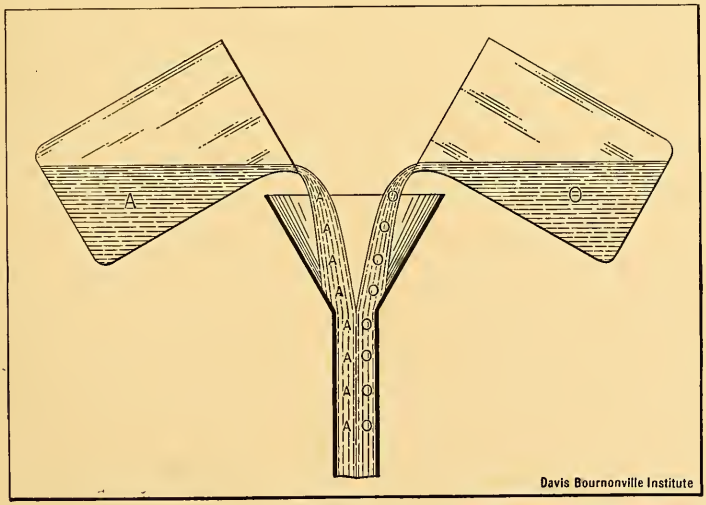

FIG. 5.—SHOWING HOW GASES MAY PASS THROUGH MIXING TUBE WITHOUT MIXING IF NOT BROKEN UP.

then Fouché could develop his torch. The development of the liquid air process of deriving oxygen from the atmosphere a few years later completed a cycle of discovery which made possible a great commercial development. It has transformed the old art of welding and made it one of the most advanced methods of fabrication.

The Davis-Bournonville Oxy-Acetylene Welding Torch

We have in the foregoing tried to give you an idea of the importance of the oxy-acetylene torch development and what it has meant from scientific standpoint. The first oxy-acetylene torches used in this country were introduced by Mr. Eugene Bournonville, formerly of the Davis-Bournonville Company, and Mr. Augustine Davis, president of the company, was one of the chief pioneers in its commercial development.

Here is a Davis-Bournonville oxy-acetylene welding torch. It is a simple device, consisting of a handle, two needle valves, two tubes for the oxygen and acetylene, head and tip. The tubes are silver soldered in the head and fixed in the handle so as to give them stability and strength. The head is made with a conical seat and is threaded at the mouth for a nut which holds a tip with a conical head in position. The upper tube is connected to the oxygen supply as you will see by tracing the black hose to the oxygen cylinder. The lower tube is joined to the acetylene cylinder by the red hose.

The Interchangeable Tip System

One of the very important and valuable features of the Davis-Bournonville torch is the system of interchangeable tips. There are many styles and sizes of interchangeable tips provided for this torch, all of which designed for a given size of torch may be used in the same torch head at will. Hence, you have the means of producing many sizes of flames from the smallest to the largest required in commercial welding for which a given style of torch is adapted.

The choice of tip is very important as the size of flame

should be proportional to the thickness of material to be welded and as the size of flame is governed by the size of tip, you must consult the table giving the sizes of tips for various thicknesses of metal until you become so familiar with torch practice that you will instinctively use the right size tip.

The Mixing Head or Carburetor

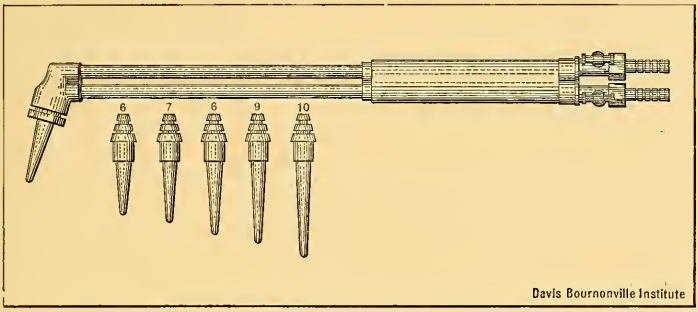

FIG. 6.—LARGE STYLE C WELDING TORCH AND TIPS.

The intimate mixing of the acetylene and oxygen gases is accomplished in the conical end of the tip where it fits into the torch head. This part is identical in function with the carburetor of a gas engine of a motor car. The carburetor provides for mixing a certain definite amount of air with the vaporized gasoline thus forming a combustible and explosive mixture. The carburetor in the torch tip is the mixing chamber where the oxygen flowing longitudinally through the tip meets the cross currents of acetylene gas flowing in through the holes in the sides. The cross currents form a vortex or whirlpool, mix and flow through the longitudinal passage to the end of the tip where they burn.

The diameter of the holes in the tip and the pressures of the respective gases determine the quality of the mixture. The diameters of the holes are graded, and the tips are numbered to correspond. A low number tip means small diameter gas passages and a small flame suitable for welding thin metal, whereas a high number tip means comparatively large gas passages and a large flame suitable for welding thicker metal. The

following table compiled by the Davis-Bournonville Company represents the result of years of experience in welding practice.

Acetylene and Oxygen Pressures

DAVIS-BOURNONVILLE STYLE C WELDING TORCHES
with Style 99 and 100 Tips

Tip No.	Thickness of Metal Inches	Acetylene Pressure Lbs.	Oxygen Pressure Lbs.	Acetylene* Consumption Per Hour	Oxygen* Consumption Per Hour
00	Very	1	1	0.6 cu. ft.	0.8 cu. ft.
0	Light	1	2	1.0 "	1.3 "
1	1/32–1/16	1	2	3.2 "	3.7 "
2	1/16–3/32	2	4	4.8 "	5.5 "
3	3/32–1/8	3	6	8.1 "	9.3 "
4	1/8–3/16	4	8	12.5 "	14.3 "
5	1/4–5/16	5	10	17.8 "	21.3 "
6	5/16–3/8	6	12	25.0 "	28.5 "
7	7/16–1/2	6	14	33.2 "	37.9 "
8	1/2–5/8	6	16	42.0 "	47.9 "
9	5/8–3/4	6	18	58.0 "	65.9 "
10	3/4–up	6	20	82.5 "	94.0 "
11	Extra	8	22	89.0 "	101.2 "
12	Heavy	8	24	114.5 "	130.5 "

Operators frequently adjust the pressure regulators from one to two pounds above the figures given in the table to allow for gauge variations and drop of pressure when the gases are supplied in cylinders.

* Gas consumption per hour is the maximum with torch burning continuously.

This table gives the tip number, the thickness of metal for which it is suited, the acetylene pressure and the oxygen pressure and the hourly consumption of each gas when torch is used continuously.

The No. 00 tip should be used in the Small Style C torch for welding metals of the thinnest gauges only. It uses very little gas and the regulators should be set for one pound per square inch acetylene pressure and one pound oxygen pressure. The next tip is No. 0. This also is used only on very thin materials and little gas pressure is required. The acetylene pressure should be one pound, the oxygen pressure two pounds. The No. 1 tip is suitable only for light gauge metals from 1/32 to 1/16 inch thick. The gas pressure should be the same as for the No. 0, or one pound acetylene and two pounds oxygen.

The tips, as you already know, are readily interchangeable. To change tips is simply a matter of loosening the tip nut, removing the tip and replacing it with another and screwing the nut firmly to place. The operation takes but a few moments, and there is no excuse for not changing the tip and using the one best suited to the work. Even if you have only an inch of welding to do it is better to change the tip than to fuss along with a flame too large or too small. It is a bad habit to fall into, and should be avoided.

You will note in the table that the No. 6 tip which is provided for use with the large Style C torch should be used for metals from 5/16 to ⅜ inch thick, and that the acetylene pressure should be six pounds and the oxygen pressure twelve pounds. The acetylene pressure is the same as the number of the tip and the oxygen pressure is two times the number of the tip, or twelve pounds. This rule holds for all tips from No. 0 to 6 inclusive but it does not hold true with the higher numbers of tips. The No. 12 tip requires an acetylene pressure of 8 pounds and oxygen pressure of 24 pounds. However, the rule of setting the acetylene pressure to the number of the tip, and making the oxygen pressure two times the number of the tip holds true throughout a large range of commercial welding.

When using gases from acetylene and oxygen cylinders it is customary to break the rule to the extent of making the working pressures slightly more than the theoretical or table pressures when starting to weld. This is done to compensate for the loss of pressure as the gases are used from the cylinder. Regulators are likely to let the working pressure drop as the cylinder pressure falls; hence it is customary when using gases from cylinders to set the regulators to one or two pounds above the table pressures. But when the gases are supplied through the pipe lines, as they are in the welding institute workroom, they are under nearly constant pressure, and you should set the regulators closely to the pressures specified in the table.

Care of Torch and Tips

When changing the tips be careful to wipe the tip clean so that no dust or foreign substance will remain on the conical

ground seat and prevent it fitting closely in the head. If this precaution is not observed you are likely to have trouble from the gases leaking by the tip and causing flashbacks and other troubles. Always keep the tips standing vertical in a suitable box or holder, and keep them covered. This will insure the conical ground seats being protected from bruising and collecting dust.

The needle valves seldom give trouble. If one should develop a leak it is doubtless due to dirt or scale getting on the seat and preventing the conical point seating properly. It can be readily removed and the foreign substance cleaned out. In general, however, avoid taking apart unnecessarily. Follow the very good rule of not tinkering with any apparatus when it does not require it.

The oxy-acetylene torch is a simple and durable apparatus but it is not fool-proof. Always hang it up when through with it. Don't let it lie around on the bench as something may fall on it and spring it out of shape. Never use the head as a hammer. If you knock the work around with it you are likely to injure it and cause trouble. The head casting is bronze and though the bronze is of high tensile strength and great durability it is easily dented by a blow. If dented the conical seat will be distorted and the tips will not fit; consequently the gases will leak by the tip and cause trouble. The late model torches have drop-forged heads and these also should be handled carefully.

When using the torch take good care of the end of the tip. If you let it drop occasionally into the puddle you are likely to cause a flashback or melt the end of the tip, distort its shape and perhaps clog the hole. A good workman is known by the way he cares for his tools, and the oxy-acetylene welding operator is no exception to the rule. Never attempt to remove the tubes in the head. They are sweated in with silver solder and can only be taken apart by an expert who is provided with the proper tools and apparatus. If your torch requires a new head, it should be sent to the factory where it will be inspected and the defective parts will be replaced.

Questions

1. What is the form of the simple blowpipe used by jewelers?
2. What is a simple Bunsen burner?
3. Where is the oxygen taken from to supply the flame of a simple Bunsen burner?
4. What is the source of oxygen in a shop Bunsen torch using illuminating gas and compressed air?
5. Who discovered the oxy-acetylene blowpipe?
6. What is the blowpipe called in America?
7. What is the mixing chamber like in principle?
8. Where is the mixing chamber in the Davis-Bournonville torch?
9. Is the interchangeable tip system advantageous? Why?
10. What are the needle valves? The handle? The tubes? The head?
11. How is the tip held in the head?
12. What pressures of gases are required for welding ¼-inch steel?
13. What size of tip should be used for welding ⅜-inch metal?
14. How is the head secured to the tubes?
15. What is the danger of letting a flashback burn in the tip?
16. How close should the tip be held to the metal when welding?

Notes

Notes

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DAVIS-BOURNONVILLE
OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

EXPLOSIVE GAS MIXTURES— FLASHBACKS AND BACKFIRES

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

Form 379

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EXPLOSIVE GAS MIXTURES—FLASH-BACKS AND BACKFIRES

Combustion of Common Fuel Progressive—Combustion of Air and Combustible Gas Mixture Sudden and Explosive—Coal Mine Explosions Due to Mixture of Mine Gas and Air—Flame Propagation—Principle of Davy Mine Safety Lamp—Application in Oxy-Acetylene Torch—Flashbacks and Backfires—Importance of Correct Procedure in Starting to Weld—How to Set up the Apparatus and Blow Out Foreign Substances—What to Do in Case of Stoppage.

When a candle is lighted the wick takes fire and the wax beneath melts and forms a pool of liquid which saturates the wick and feeds the flame. As the candle burns it becomes shorter and shorter. The burning or combustion of the wax or wick is progressive and practically constant. So it is with ordinary fire. If we start a fire of sticks and shavings the fuel is progressively consumed. The rate of combustion may not be constant, however, as that will depend on how the fire is built and whether it is in a firebox or open grate, but the fuel does not burn all at once. It burns until the wood is gone, and then it goes out. When you light a gas-jet, the rate of combustion is constant. The gas burns as it escapes from the jet; the flame remains practically the same size, and the consumption of gas is a certain number of cubic feet per hour.

Combustion of Air and Combustible Gas Mixture Sudden and Explosive

But if we let some gas escape unburned into a bottle and then apply a match to the opening we get instantaneous combustion and an explosion. The gas mixes with the air when it enters the bottle and forms a mixture that burns instantly. When the match was applied to the mouth of the bottle the flame spread instantly in all directions, and the gas and air combined in a fraction of an instant. The result was a tremendous expansion of the air and gas due to the heat produced, and a loud noise or report.

Explosive mixtures of gas and air are always dangerous and should be avoided. Never look for a gas leak in the cellar with a lighted candle; you are likely to be a subject for the coroner if you do. The gas escaping into the cellar mingles with the air and forms an explosive mixture which may be of sufficient volume and power to blow the house from its foundation and kill the occupants.

Coal Mine Explosions Due to Mixtures of Mine Gas and Air

Coal mine explosions occur in coal mines in which accumulations of combustible gases are released by removal of the coal. The explosion is caused by the accidental ignition of the mixture of this coal gas and the air which has reached the explosive state. It is a curious fact that a mixture of combustible mine gas and air is not explosive when the proportion of gas to air is much greater than a certain figure

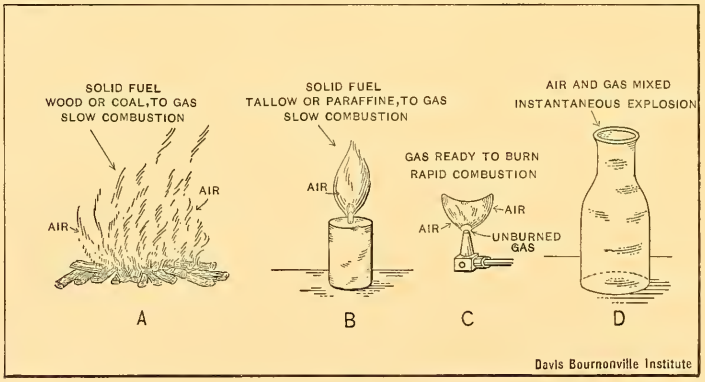


FIG. 1.—OPEN FIRE, CANDLE FLAME, GAS JET AND INSTANTANEOUS COMBUSTION COMPARED.

generally about 10 to 12 per cent; neither will a mixture of mine gas and air explode if less than a certain figure, say about 8 to 9 per cent. While the over-rich mixture is non-explosive up to a certain figure it again becomes explosive when very rich. Thus, we have the condition first of the non-dangerous mixture of gas and air up to about 8 or 9 per

cent dilution depending on the quality of the gas; from 8 to 12 per cent is a highly dangerous mixture; and from 12 per cent to about 80 per cent or 85 per cent may not be violently explosive but slightly greater dilution may again create an explosive condition. Acetylene gas, however, forms an explosive mixture with air when the mixture reaches 3 per cent acetylene. All gas mixtures in closed places are potentially dangerous and should be treated very cautiously. The odor of acetylene is noticeable when a very small percentage is present, and the warning should never be disregarded in closed places.

Flame Propagation—Principle of Davy Safety Lamp

Extensive experiments conducted by the Bureau of Mines to determine the explosibility of gas mixtures have not only determined the percentage of gas mixture that is dangerous but they have also determined the rate of flame propagation in an explosive mixture. Many hard coal mines would be unworkable were it not for the Davy safety lamp. The safety principle of this lamp was discovered by Humphrey Davy many years ago and it has proved to be one of the most valuable safety devices. The safety feature of the Davy lamp is very interesting as it has an important bearing on the action of the oxy-acetylene torch. Humphrey Davy discovered that an open flame in the miner's lantern could be made safe by surrounding it with a fine mesh metal gauze—in other words, woven wire cloth. The gas and air entering the lantern through the gauze burns quietly and without explosive effect. Remove the wire gauze envelope and immediately the surrounding gas laden air takes fire and explodes.

The reason for this apparently strange action is easy to understand when explained. Flame is incandescent gas; it is gas in the state of combustion. If the flame is cooled it disappears and no longer ignites an adjacent combustible mixture. The metal gauze cools the flame spreading from the light and prevents its propagation.

We have here two candles. One is lighted and the other is not. When we touch the flame of the lighted candle to

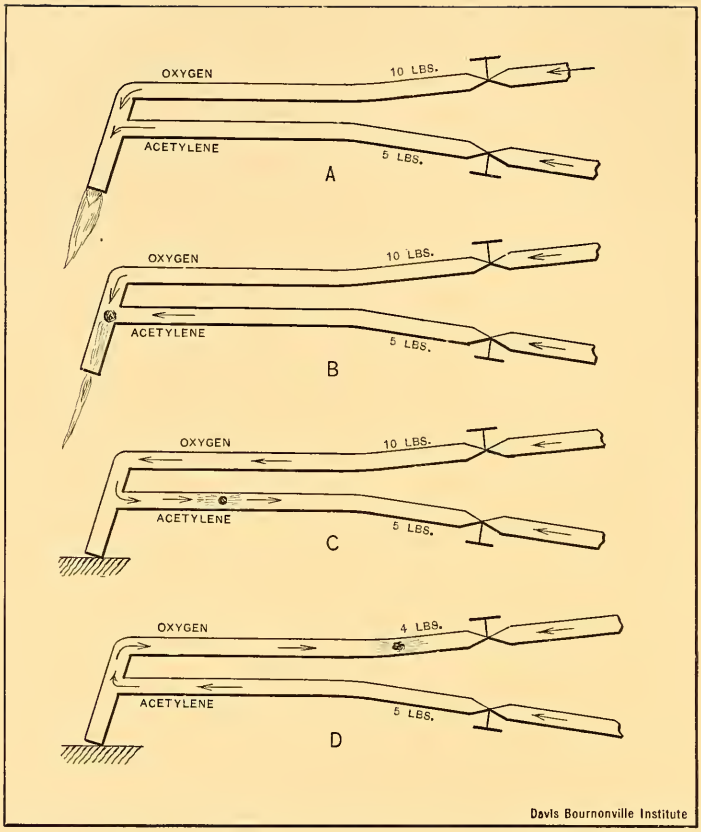


FIG. 2.—SHOWING THREE CONDITIONS OF FLASHBACK, TWO OF WHICH HAVE DEVELOPED BACKFIRE.

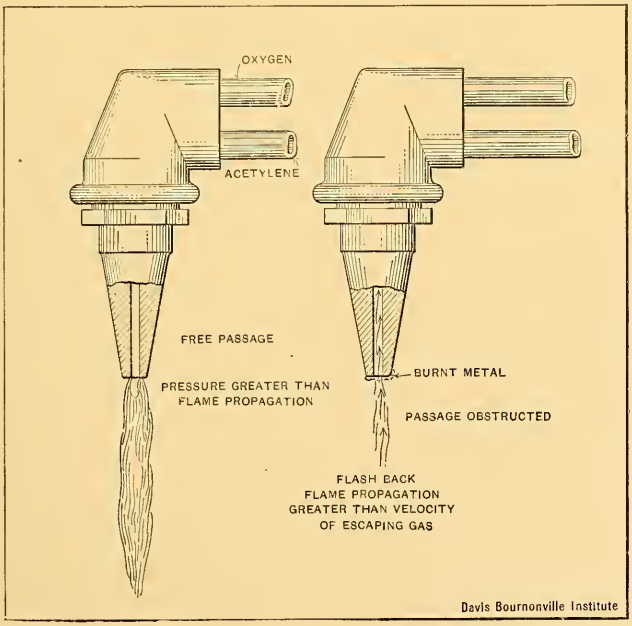
the wick of the unlighted one it immediately takes fire and burns. Now we will blow one candle out and bring the flame of the other close to the wick but not touching it. It immediately takes fire. Why? The gas escaping from the hot wick is combustible and the adjacent flame starts combustion.

Now we will blow the candle out again and bring the lighted one close to the wick as before but with this fine wire gauze between. The unlighted wick no longer catches fire when the flame is brought close to it. In fact, it will

not take fire when the gauze is placed directly against the wick, and the lighted candle is brought close up to the gauze. Why is this?

The reason is that the gauze being metal and comparatively cool reduces the temperature of the flame below the igniting point. The metal radiates the heat rapidly and we could hold the flame close to the wick with the gauze between for a long time before the metal would get hot enough to fire the unlighted wick.

This, then, is the principle of the Davy safety lamp. The explosive air and gas passes through the gauze to the flame and burns but the flame cannot propagate through the gauze because the moment it reaches the gauze it cools below the igniting point. The gauze, in fact, is a refrigerator or icy barrier that stops the flame and thus preserves the miner from the dangers of a mine explosion.



FIGS. 3 AND 4.—SHOWING NORMAL FLAME AND FLASHBACK FROM EXTERIOR.

Application in Oxy-Acetylene Torch

You have the Davy principle in effect in the tip construction of the oxy-acetylene torch. The holes through which the combustible gases enter the mixing chamber are of small diameter and comparable in dimension to the mesh of the wire gauze in the safety lantern. If the flame tends to follow the mixture of oxygen and acetylene back into the tip and into the head the tendency is checked ordinarily by the rapid flow of the gases and the cooling effect of the tip. Under normal working conditions the head and tip are comparatively cool and the flame entering the tip is extinguished. Moreover, the velocity of the escaping gases is high, and in excess of the flame propagation rate. Should, however, the tip become very hot and the flow of gases be momentarily checked, then it is possible for the flame to enter the tip and pass back into the mixing chamber and burn there. This is called a flashback. If a flashback penetrates beyond the mixing chamber into the torch handle, hose, or even to the regulator chamber, it is called a backfire.

Flashbacks and Backfires

The terms flashback and backfire are loosely interchanged but there is a well defined difference which should be clearly understood by all using the oxy-acetylene apparatus. The first is a more or less petty annoyance due to local conditions, while the other is serious and demands an investigation to determine the cause. To make the distinction clear we will again state the action of each and the causes that produce them.

A flashback is the snapping out of the flame and penetration of the flame into the torch tip or mixing chamber. It is generally caused by an obstruction in the tip such as a globule of metal adhering to the end or by holding the tip too close to the puddle and thus obstructing the flow of gas so that the flame is able to propagate back to the mixing chamber. A flashback is checked by shutting off the oxygen needle valve. The fire in the torch is immediately extinguished and the pure acetylene gas issuing from the tip may be relighted and then the oxygen needle valve opened

and adjusted as before. Overheating of the tip due to use on a preheated casting or long continued welding in a closed place may cause popping back. Cooling of the tip may then be necessary but ordinarily the Davis-Bournonville torch never requires dipping into a pail of water to keep it cool.

A backfire is a much more serious matter than a flashback as it may burn or burst a hose and scare the operator. In a manufacturing welding room where operators are close together a bursting hose might cause a panic and result in the injury of some of the welders, especially if girls. A backfire results in the penetration of the flame through the torch into the handle, hose or pressure regulator and is caused by an accumulation of mixed gases due generally to faulty manipulation of the cylinder stop valves, improper regulator adjustment, incorrect procedure of turning on and lighting gases or dipping the tip into the puddle. It is of the utmost importance that welding operators be required to follow a fixed procedure in turning on and lighting the torch both for their own safety and the safety of others. Even though a backfire may cause no more damage than the bursting of a hose, that is serious enough. A burst hose means the destruction of property and time lost in replacing it. It is a reflection on the operator's ability and may cause the uninformed observer to conclude that there is something radically wrong with the whole apparatus.

We have given considerable attention to the principle of the Davy safety lamp. Do not get the idea that the metal gauze strainers in the gas regulators are effectual barriers to flame propagation, however, because unfortunately they are not. The heat of the oxy-acetylene backfire is so intense that the cooling effect of the gauze is overcome, the gauze melted and the flame passed on beyond. This will give you an idea of the intensity of the heat at your command. The gauze strainers may tend to check the flame but they cannot be depended on with certainty. The function for which they are designed is to stop scale and dirt from entering the torch and clogging the tip.

The illustration, Fig. 2, shows in diagram four conditions of combustion that may develop in the oxy-acetylene torch

apparatus. The normal condition is shown at A for a welding torch in which acetylene is supplied under five pounds pressure and oxygen under ten pounds pressure. The proportions of the mixing head or carburetor and the outlet are such as to give a stable flame. But at B the balance has been lost due to overheating of the torch head, obstruction in the tip or an excessively oxidizing flame. The flame has popped back or propagated to the mixing chamber where it continues to burn. This is a flashback. A more serious condition is shown at C which may develop as a consequence of holding the tip immersed in the puddle causing a flashback and prolonging the abnormal state. The outlet is stopped and the oxygen pressure being in excess of the acetylene pressure tends to equalize which results in the oxygen flowing back into the acetylene tube and burning there. This is the propagation of the flashback into the hose and is known as a backfire.

A condition similar to C is shown at D but the oxygen pressure being less than the acetylene pressure the flashback is propagated into the oxygen hose. This is a serious hazard as it invariably ends in burning the oxygen hose and spattering burning molten rubber over the surroundings. It is an inherent hazard of the equal pressure or balanced pressure torch.

The three conditions shown are the result of a flashback and its propagation. A backfire is regarded as a propagation of a flashback into mixed gases, and may take place in the torch handle, hose, regulator or even as far back as the acetylene generator if proper safeguards are not provided in the acetylene gas line.

Importance of Correct Procedure

In the lecture "Regulating Gas Supply" detailed instructions were given for opening the valves and gas regulators. You were told to open the cylinder valve on the oxygen cylinder first, and to open it very slowly but to open it full. The reason for opening it slowly is that a sudden rush of oxygen gas at a pressure of 1,800 or 2,000 pounds per square inch may injure the diaphragm in the gas regulator and make

it unworkable. The reason given for opening the valve as far as it will go is to prevent leakage around the stem. The cylinder valve is made with two seats, one of which acts in the ordinary manner to check the flow of gas while the other backs up against another seat beneath the stuffing-box end and prevents the leakage around the stem when the valve is open.

You were directed to open the oxygen valve first and to regulate the oxygen regulator while the oxygen needle valve is open. The reason for having the needle valve open is that you will be unable to adjust the working pressure accurately if the gas is not escaping the same as when being used. The reason for opening the oxygen valve first and regulating the flow is to prevent forming a mixture with the combustible in the torch tubes or hose. Oxygen is not combustible; it supports combustion only. You cannot light the oxygen gas when it is escaping from the tip alone, but you can light the acetylene when it is escaping from the tip alone —because the flame takes the necessary oxygen from the air.

Now consider what might happen if the acetylene gas valve was opened first and the acetylene regulator was adjusted first. The torch would be filled with acetylene gas, and when the oxygen was admitted the operator might not let it flow long enough to clear out all the acetylene and oxygen mixture. The result may be a disagreeable backfire when the gas is lighted. Even if no damage results the effect on the nerves is something to be avoided.

Causes of Trouble Reviewed

To reiterate, there is little danger of flashbacks and backfires if the operator knows his business and attends to it. He needs only to follow the rules in opening the valves, regulating the gas supply and manipulating the torch to avoid them. Under normal conditions the flame cannot enter the torch or hose. The velocity with which the gases escape is greater than the speed of the flame traveling in an explosive mixture. The gas coming out pushes the flame ahead of it and keeps it at the tip where it belongs. Experiments have

shown just how quickly a flame spreads in an explosive gas mixture. This rate or speed called the "speed of flame propagation" is from 300 to 600 feet per second, depending on conditions, the gases, etc. We can burn an explosive mixture of acetylene and oxygen at the tip if the speed of the gases escaping is greater than the rate of flame propagation. If the speed of the gases escaping is greater than the rate of flame propagation, the flame cannot enter the tip and follow back into the hose; the gases are coming out faster than the flame can travel against them. Keep this fact in mind and avoid doing anything that removes this safeguard.

When the valves are properly adjusted a flashback or backfire can occur only when something checks the flow of gas or the head and tip become overheated. If you hold the tip too close to the metal you may check the flow of gas so that the flame can enter the tip. This will cause the flame to pop out sometimes, but very rarely will it follow back into the hose.

How to Set Up Apparatus and Blow Out Foreign Substances

If care is not taken to blow out the hose before connecting up, loose dirt may enter the torch and clog the tip so that the gas cannot flow freely. The operator should follow a certain set procedure when setting up welding or cutting apparatus as follows:

1. Before attaching the oxygen regulator to the cylinder "crack the valve" to blow out any dirt that may have lodged in the opening.
2. Clean off any dirt that may have lodged on the nipple connection of the regulator, and shake it with the opening down so that any loose dirt within will rattle out.
3. Connect the regulator to the gas cylinder and crack the cylinder stop valve slightly and blow gas through the regulator for a moment.
4. Connect the hose to the regulator and again blow through.
5. Connect the hose to the torch, open the needle valve and again blow through.

6. Repeat the procedure with the acetylene regulator and hose connection.

If in the course of welding or cutting the torch begins to give trouble and the cause is suspected to be some foreign substance, proceed as follows to remove it:

Disconnect the hose from the torch and blow each hose out separately. Remove the torch tip and open the needle valves, and insert the nipple of the oxygen hose into the head and blow through. This should remove any ordinary obstruction.

Above all, avoid getting excited when things don't work properly. Remember always that fixed laws govern the workings of the oxy-acetylene apparatus the same as of everything else. If it refuses to work satisfactorily there is a cause, and it is up to you to find it and remedy the trouble.

Questions

1. What sort of combustion takes place in a coal fire?
2. Why does a mixture of air and gas explode?
3. What is an explosion?
4. What is the rate of flame propagation in a coal mine explosion?
5. Why does the Davy safety mesh prevent firing explosive mixtures in mines?
6. Is the Davy screen effective in oxy-acetylene apparatus? Why?
7. Does the cooling principle apply at all in the torch?
8. What is a flashback?
9. In what respect does a flashback differ from a backfire?
10. What should be done immediately when the flame pops back?
11. How many conditions of flashback and backfire are recognized?
12. Is a certain set procedure important in starting to weld?
13. What should be done first in setting up the equipment?
14. How do you blow out the torch if it becomes stopped?
15. What advice should be observed when things go wrong?

Notes

DAVIS-BOURNONVILLE
OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

HEAT AND TEMPERATURE

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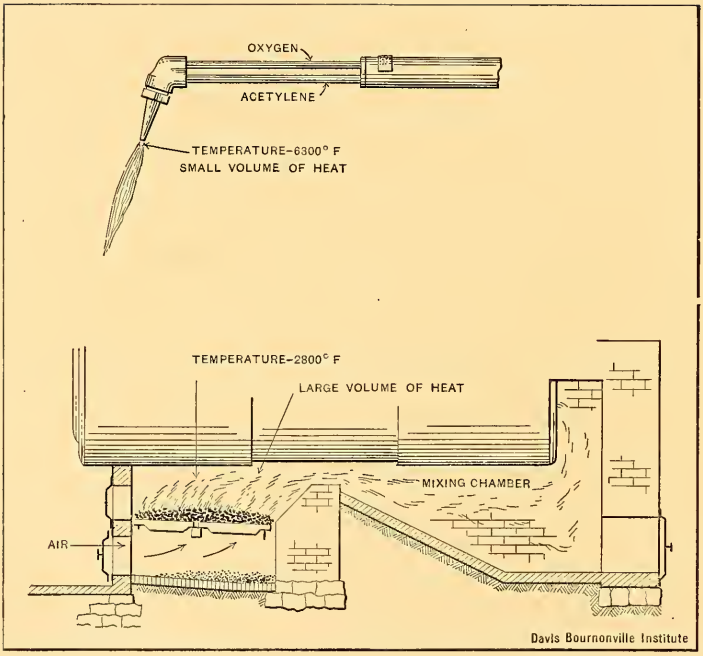

HEAT AND TEMPERATURE OF OXY-ACETYLENE TORCH AND BOILER FURNACE COMPARED

HEAT AND TEMPERATURE

Heat and Temperature Not the Same—Radiation, Convection and Conduction—British Thermal Unit Measure of Heat—Temperature Measured with Thermometers or Pyrometers—Expansive Effect of Heat—Specific Heat—Oxy-Acetylene Torch Means of Producing High Temperatures.

You probably think of heat and temperature as one and the same thing, but they are not the same; it is highly important that you clearly understand the difference and are able to make the distinction. You will understand the oxy-acetylene torch action much more clearly when you realize the difference between a large fire and a very hot fire.

A Large Fire may be no Hotter than a Small One —Radiation—Convection and Conduction

A large fire is not necessarily a very hot fire. A large fire fire gives off a great amount of heat, but the temperature may never rise much above 2000 degrees Fahrenheit. When an open fire, burning any combustible like wood, rises to a certain temperature it can become no hotter, no matter how long it burns or how much fuel is added. There is a limit to the intensity of combustion, but the limit to the amount of heat produced is the amount of fuel consumed. If heat must be provided for a small room, a small coal stove or a gas-heater will be sufficient, but if a whole house is to be heated a large furnace must be used. The temperature of the furnace fire will be little higher, if any, than the temperature of the small coal fire, but the furnace will give off a much greater volume of heat, and it will warm more rooms than the small coal stove, because more coal can be burned in the furnace than in the small stove.

Heat is dissipated by radiation, convection and conduction. Heat rays are invisible. A fireplace warms a room by radiated heat chiefly, the rays from the fire give the body the sensation of warmth and comfort on the side facing the fire, even when the air in the room is comparatively cold. A steam radiator heats the air and radiates invisible heat rays also. The fireplace fire

is inefficient because most of the heat goes up the chimney with the smoke and gases of combustion. The steam radiator heats chiefly by convection; the air circulating over it finally fills the room and all parts become warm. Heat travels by conduction in a metal piece. If one part is made very hot the heat flows to the colder parts and warms them. When you hold the red hot end of a steel bar near your face you feel radiated heat. If you hold your hand over the bar you will feel hot air rising from it; that is heat of convection, and if you hold the bar long enough it will become unpleasantly hot at the lower end. That is due to conducted heat. Remember that heat tends always to equalize the temperature by traveling from hot zones to cooler ones.

Heat Can Be Measured

The practical man is likely to look upon science as being something impractical and beyond his comprehension. But that is a very erroneous view. While *some* scientists are impractical in workaday matters they have, as a class, found out the methods of weighing and measuring imponderable substances and unseen forces, and thus making them available for practical purposes. Now when you can measure something or weigh it you ca ı deal with it understandingly. It no longer is mysterious. Electricity was a very mysterious and incomprehensible force until the scientists learned how to produce it, to measure its capacity, to weigh its force and to control and direct it. Then the practical man could apply it to useful purposes.

Heat can be measured and the amount of heat in a pound of coal may be accurately determined. Heat is measured by thermal units, or in calories in the French system used by scientists. A British thermal unit is the amount of heat required to raise the temperature of 1 pound of water 1 degree Fahrenheit. If one pound of water is raised in temperature 100 degrees it has absorbed 100 British thermal units. (Abbreviated to B. T. U.) A pound of clean coal when so burned as to secure perfect combustion generates about 13,000 B. T. U., a pound of kerosene about 20,000 B. T. U., and a pound of acetylene about 23,000 B. T. U. Authorities differ on these figures, especially on acetylene.

Thermometers Used To Measure Temperatures

The intensity of the source of heat is the temperature. Temperatures are measured with thermometers or pyrometers. A glass thermometer may be used when the temperature is comparatively low, say up to 400 or 500 degrees Fahrenheit. High temperatures, such as are encountered in a furnace, are measured with pyrometers. The common form of a pyrometer comprises two dissimiliar metal wires which are twisted together at one end, and separated by some insulating material like porcelain that withstands a high heat. The twisted ends of the wires are thrust into the furnace. The other ends are connected to a millivolt meter which records the feeble electric current produced by the metal couple when highly heated. The graduations on the the dial of the millivolt meter indicate the temperature in degrees.

Another form of pyrometer works on the optical principle. The light emitted by the furnace is compared with the filament of an incandescent electric lamp, and by this comparison the observer is able to tell the temperature of the furnace.

The temperature of this room is measured by a glass thermometer. It registers about 68 degrees Fahrenheit. This is a Fahrenheit thermometer because it has the Fahrenheit scale. The two standards of measuring points of the Fahrenheit scale are the melting point of a mixture of finely chopped ice and salt, and the boiling point of pure water at sea level. The melting point of ice and salt is called zero. The space on the tube between the zero point and the boiling point is divided into 212 graduations called degrees. Pure water freezes at 32 degrees on the Fahrenheit scale. Therefore there are 180 degrees between the freezing and boiling points.

Thermometer Scales

The Fahrenheit scale is commonly used in shops and factories and is the common scale of every-day use to indicate the temperature outdoors and indoors. There is another thermometer scale commonly used in scientific work called the Centigrade scale. In the Centigrade scale the zero point is the freezing point of pure water at sea level and the boiling point is the other ex-

treme of the scale. The space between the freezing and boiling point is divided into 100 parts, each of which is called a degree. There is still another thermometer scale—the Reaumur—but little used and seldom referred to in text books. The zero point is the temperature of freezing pure water and the space between this and the boiling point is divided into 80 parts or degrees.

In the Fahrenheit scale there are 180 degrees between the freezing point and the boiling point of pure water at sea level, while in the Centigrade scale there are only 100 parts. Hence, it is apparent that the Fahrenheit and Centigrade degrees are not the same; 1 degree Centigrade is equal to 1.8 degree Fahrenheit. The Centigrade scale is generally used, as we have said, for scientific work and the Fahrenheit scale is used for common purposes. When temperatures are mentioned hereafter in these lectures they will be in the Fahrenheit scale. The abbreviation for Fahrenheit is F. and for Centigrade C.

From the foregoing it should be clear that temperature may be compared to pressure while heat may be compared to volume or quantity. We may use the water pipe analogy. If a water pipe carries water under pressure, the pressure can be determined by the use of a pressure gauge. The temperature of the water would be determined by a temperature gauge or thermometer. The amount of water flowing through the pipe could be measured by a meter. We have no simple meters for heat but you can imagine that the amount of heat could be measured by something like a meter. We are, in fact, able to determine the amount of heat in a given volume of water, very readily from the temperature, the weight of the water and its specific heat.

Specific Heat

Specific heat is the quantity of heat required to raise the temperature of a body 1 degree in comparison with water; water is the standard. The specific heat or heat capacity of metals is less than that of water. The specific heat capacity of some metals is much greater than others. This has an important effect on welding with the oxy-acetylene torch. A metal that has high specific heat, or heat capacity is more difficult to weld than one

that has low specific heat. This is a characteristic quite different from the melting point. The melting point may be comparatively low while the specific heat is high as is the case of aluminum.

What has been said should make it clear that heat and temperature are not the same, but they are closely related. There can be no heat without temperature, and no temperature without heat. The higher the temperature the more rapidly will the heat flow to bodies of lower temperature. The higher the temperature of your torch flame the more quickly will it melt the steel or cast iron. The temperature of the hottest part of the oxy-acetylene flame is about 6300 degrees F. It is so high that almost all solid substances melt and run like water when exposed to it. The temperature is the highest known with the exception of the electric arc. The temperature of the electric arc is supposed to be about 7800 degrees F.

Expansion and Contraction

Changes of temperature affect the length, breadth and thickness of a metal piece. If the temperature is raised the part expands and if the heat is abstracted and the part cools it shrinks. The changes are proportional to the changes of temperature within a wide range of limits. If you know that a steel bar two feet long is to be heated up 1000 degrees F. you can calculate very closely the amount of expansion, and make allowance for it. The change in length due to change of temperature is called the coefficient of expansion or contraction, and it has been determined for all the metals. The coefficient is a factor generally expressed as a fraction of inch and for 1 degree. A cast aluminum bar expands over 5/32 inch to the foot when heated from 60 degrees F. to the melting point, or 1218 degrees.

Amount of Heat Produced by Torch is Small

Notwithstanding the fact that the hottest part of the oxy-acetylene torch flame has a temperature of over 6000 degrees F. the *amount* of heat given off by a torch flame is comparatively small. We can get much more heat from the blacksmith's forge because we burn much more fuel, and produce more thermal

units in a given time, but we cannot get the high temperature. The temperature of the hottest forge fire is only about 2800 to 3000 degrees F.

When large masses of iron require heating to moderate temperatures, the economical method is to use a coal fire or an oil flame. The cost of the heat will be much less than when produced with oxygen and acetylene. But when the metal must be melted and welded the high temperature flame is required.

Now you begin to realize that you have in the oxy-acetylene torch a tool or instrument of extraordinary quality. Its flame is one of great intensity but remember that the zone of great intensity of temperature is confined to the white hot cone. The flame adjacent is comparatively cold. The cone tip is keen like a razor blade while the remainder is "dull as a hoe."

When manipulating the torch then it is plain that the tip of the cone—the keen razor blade—should be applied to the parts you want to melt. Don't "hoe around" with the other part of the flame if you want to make progress.

Questions

1. Are heat and temperature the same?
2. What do you understand by radiation, convection and conduction?
3. What are the measures of heat?
4. What is a British Thermal Unit?
5. What are the means used to measure temperatures?
6. What is the common thermometer scale?
7. What is the boiling point of water on the Fahrenheit scale?
8. What is the effect of heat on a bar of steel?
9. What temperature is produced by the oxy-acetylene torch flame?
10. Is the amount of heat given off by the torch flame large compared with that produced by the blacksmith's forge?

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COURSE OF INSTRUCTION

Lecture

OXYGEN AND ITS MANUFACTURE

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OXYGEN AND ITS MANUFACTURE

Oxygen a Common Element—Methods of Producing Oxygen—Liquid Air Process—Oxygen Cylinders, Tanks or Bottles—Weight of Oxygen and Oxygen Cylinders—Electrolytic Process of Producing Oxygen and Hydrogen—Pure Water Required for the Electrolyte.

From the lectures on "Combustion" and "Flame and its Structure" we learned something about oxygen and the important part it plays in the subject of combustion in general. The oxygen in the atmosphere is the supporter of life and fire. Because of its dilution the oxygen in the atmosphere cannot be made to develop the high temperature possible from the use of pure oxygen. Hence, methods of separating or producing oxygen in the commercially pure state have been very important to the art of oxy-acetylene welding. In this lecture we propose to briefly describe how oxygen is manufactured and compressed into steel bottles for distribution and use.

While it is not absolutely essential to your success as torch welders that you know all about the sources of supplies used in your work it is nevertheless highly desirable that any intelligent workman know something about the commercial side of his occupation. Most men have the ambition to be independent and run a business of their own. We hope that in the not distant future some of you at least will be running welding shops. You will then have to deal with the commercial side of the business, and the question of gases and other supplies will loom up large and important.

Oxygen a Common Element

Oxygen is one of the most common elements in this world of ours. The air we breathe is made up of oxygen and nitrogen mixed in the proportion of about 23 parts of oxygen and 77 parts nitrogen. The oceans which cover three-fourths of the earth's surface are one-third oxygen by measure and the same applies to the fresh water of lakes, rivers and streams. The earth's crust is largely made up of oxides of one form or

another but common as oxygen is it is never found in the pure undiluted state. It is either chemically combined or mixed with nitrogen in the atmosphere. It is not strange, however, that oxygen is never found in the free, pure state; it has such a strong affinity or attraction for carbon, hydrogen, metals and many of the earths that long ago in the early geological ages it formed combinations or close partnerships that can be dissolved only with difficulty. The important exception to the chemically combined state is the free oxygen in the air but it is much diluted, and although the atmosphere contains 23 parts oxygen in mixture with nitrogen and other gases it is not by any means an easy matter to separate them. It is only within comparatively recent years that processes have been developed by which the separation can be effected on a commercial basis.

Commercial methods of producing pure oxygen have had a most important influence on the development of oxy-acetylene welding and cutting. In fact, the processes could never have reached the important stage of development they now have attained had it not been for the enterprise of the concerns that developed oxygen production methods and plants for commercial distribution. The discovery of a commercial method of producing calcium carbide and cheap acetylene was only one step in the development. Cheap oxygen commercially distributed was also required in order to put the industry on a sound basis.

Methods of Producing Oxygen

There are three general methods by which oxygen may be manufactured. They are, in order of importance, as follows: the liquid air process, the electrolysis of water process and various chemical processes. Chemical separation methods were first employed for the commercial production of oxygen used in the oxy-acetylene process. It is comparatively easy to drive off oxygen from chlorate-of-potash, for example, it being necessary only to heat the chlorate in a closed retort and collect the oxygen, as it escapes. Manganese dioxide is mixed with the chlorate-of-potash but apparently takes no

part in the chemical reaction. Its effect is to reduce considerably the temperature at which the chlorate gives up its oxygen. Thus, the use of manganese dioxide saves fuel and reduces the cost of furnace upkeep.

There are other chemical processes of making oxygen, among which may be mentioned the chloride-of-lime process, the sodium peroxide process, the barium monoxide or Brin's process. None of the chemical processes are now considered commercial in this country except perhaps, for certain remote localities where it may be easier to get chemicals than bottled oxygen. The cost of the chemicals and the necessary labor are so high that the oxygen produced by chemical processes is, in general, much higher than that made by the liquid air or electrolytic processes.

Liquid Air Process

A volume could be written on the liquefaction of gases, the discovery of liquid air and the subsequent development of the fractional distillation process by Prof. Linde in 1897. The liquid air process is based on the fact that air can be liquefied by the process of compression, expansion and consequent refrigeration. High hopes were entertained of the commercial value of liquid air but they have not been realized except in the production of gases. When the air is liquefied and allowed to evaporate, the nitrogen evaporates first at a temperature of about 20 degrees F. higher than the boiling point of oxygen. Hence, if care is taken it is possible to boil out the nitrogen and leave the liquid oxygen. The oxygen thus produced is commercially pure, containing but little nitrogen and other gases and some impurities that are in the atmosphere.

The commercially pure oxygen is pumped into seamless steel bottles or cylinders for distribution and use. These steel bottles are drawn with hydraulic presses from steel billets, and though the shell is thin and light the cylinder, nevertheless, is very strong. Each cylinder is subjected to a hydraulic test pressure of about 3600 pounds per square inch to discover leaks and defects. The cylinder stop valves are provided with

safety discs designed to blow under excessive pressure or temperature. The oxygen is pumped into the cylinders to a maximum pressure of 1800 to 2000 pounds per square inch. Formerly the maximum was 1800 pounds but during the war period the manufacturers raised the pressures to 2000 pounds in order to conserve cylinders, steel and transportation facilities. A cylinder filled with oxygen to a pressure of 2000 pounds contains one-ninth more oxygen than if compressed to a pressure of only 1800 pounds. In other words, a 200-cubic foot cylinder holds 220 cubic feet when the oxygen is compressed to 2000 pounds.

Oxygen Cylinders, Tanks, Flasks or Bottles

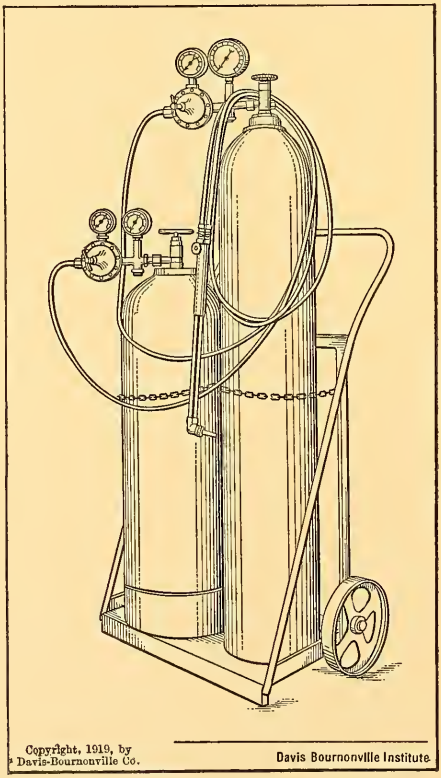

FIG. 1. PORTABLE OXY-ACETYLENE WELDING OUTFIT SHOWING TYPICAL OXYGEN AND ACETYLENE CYLINDERS

The commercial pressure containers for the gases used for welding and cutting are called cylinders, tanks, flasks or bottles. But the term cylinder seems to be preferable to tank or bottle. The term bottle is more appropriate to the seamless cylinders used for laboratory work and for physicians. The work tank ordinarily means a stationary container used under little or no pressure except that due to the weight of the fluid contained, and often it is open at the top. The term flask is seldom used to designate a gas cylinder.

Weight of Oxygen and Oxygen Cylinders

The weight of 100 cubic feet of dry oxygen is about 8.9 pounds and one cubic foot weighs 1.42 ounce. A 200-cubic foot oxygen cylinder weighs about 142 pounds when filled and 124 pounds empty, the average weight of the full and empty cylinder added together and divided by 2 being 133 pounds.

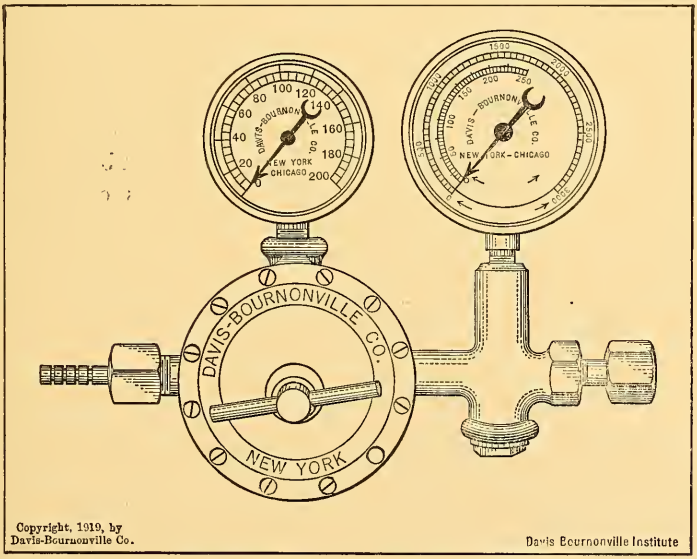

FIG. 2. OXYGEN PRESSURE REGULATOR WITH LOW PRESSURE AND HIGH PRESSURE GAUGES, THE HIGH PRESSURE GAUGE BEING GRADUATED TO INDICATE CUBIC CONTENTS AS WELL AS PRESSURE

The contained oxygen in a charged cylinder weighs close to 18 pounds.

It is not necessary, however, to resort to the weight method to ascertain the amount of oxygen remaining in a cylinder, inasmuch as the amount remaining is very nearly porportionate to the drop in pressure, if the temperature remains constant. If the cylinder pressure is 1800 pounds per square inch at the start, the drop in pressure per cubic foot withdrawn will be 1800 divided by the cubic foot capacity in feet or 200, if it is a 200-cubic foot cylinder. Hence, the drop is 9 pounds per cubic foot withdrawn. If 120 cubic feet have been withdrawn the drop should be approximately 1080 pounds and the gauge should indicate but 720 pounds pressure.

Air reduction methods of producing oxygen have developed commercially to a great importance and are, as stated, the chief means of producing commercial oxygen. But these processes have the disadvantage of requiring a costly plant that must be operated by experts and it is not feasible nor allowable for a manufacturer to produce his own oxygen from the atmosphere. The bottled oxygen must be shipped from central distribution plants, and the empty cylinders have to be returned at considerable expense and trouble. These disadvantages give to the electrolytic processes commercial advantages under some conditions, and we will describe the process and apparatus in some detail.

Electrolytic Process of Producing Oxygen and Hydrogen

The electrolytic process of producing oxygen and hydrogen from water is a fascinating study in the principles of chemistry and electricity. It is one of common chemical experiments performed in the laboratory to demonstrate the composition of water and it never fails to excite interest and wonder. It is hard for the practical man to believe that the water we drink, all the water in seas, lakes, rivers and streams and that snow and ice are composed of two invisible gases, but it is true. All water is made up of oxygen and hydrogen chemically combined in the proportion of one part oxygen to

two parts hydrogen. The familiar chemical formula for water is H_2O which means that the water molecule is composed of two atoms of hydrogen and one atom of oxygen.

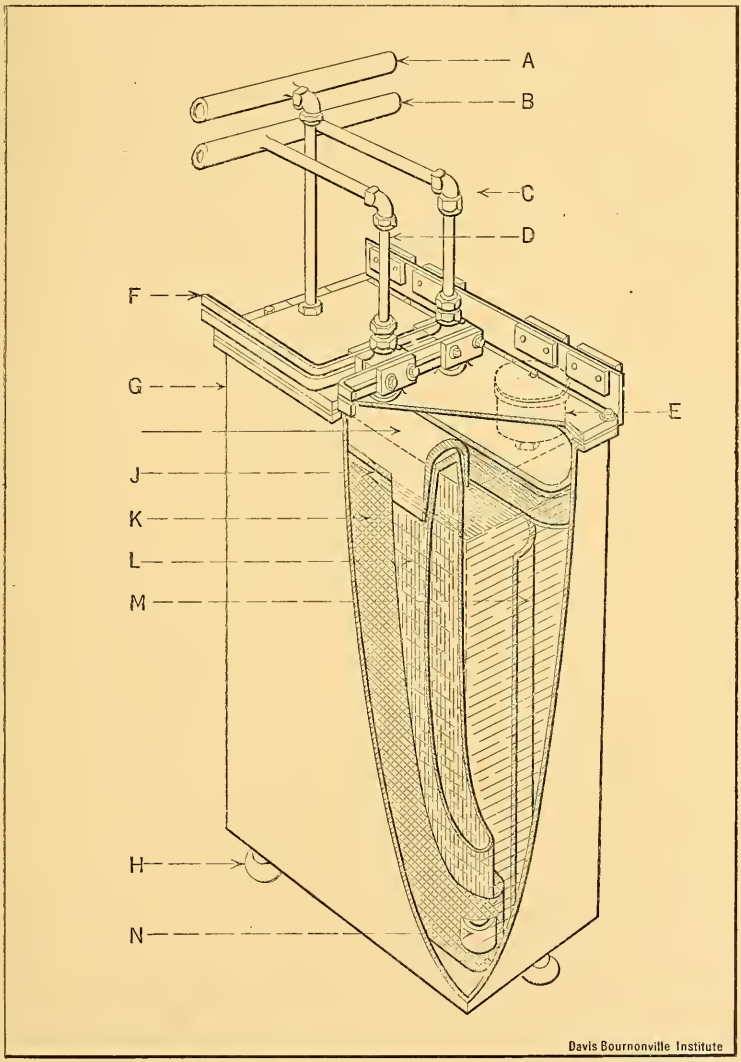

FIG. 3. DAVIS-BOURNONVIILLE ELECTROLYTIC GENERATOR FOR PRODUCING OXYGEN AND HYDROGEN FROM WATER

When water is separated into two component gases by passing a current of electricity through it the hydrogen collects on the negative electrode and the oxygen on the positive electrode. It is then merely a matter of cell construction to keep the gases separated and to provide means for drawing off the two gases into separate containers where they are immediately ready for distribution and use. But, of course, there is much more to the apparatus for separating oxygen and hydrogen from water than in the simple experimental apparatus used in the laboratory for demonstration purposes. Although apparently simple, the fact is that the development

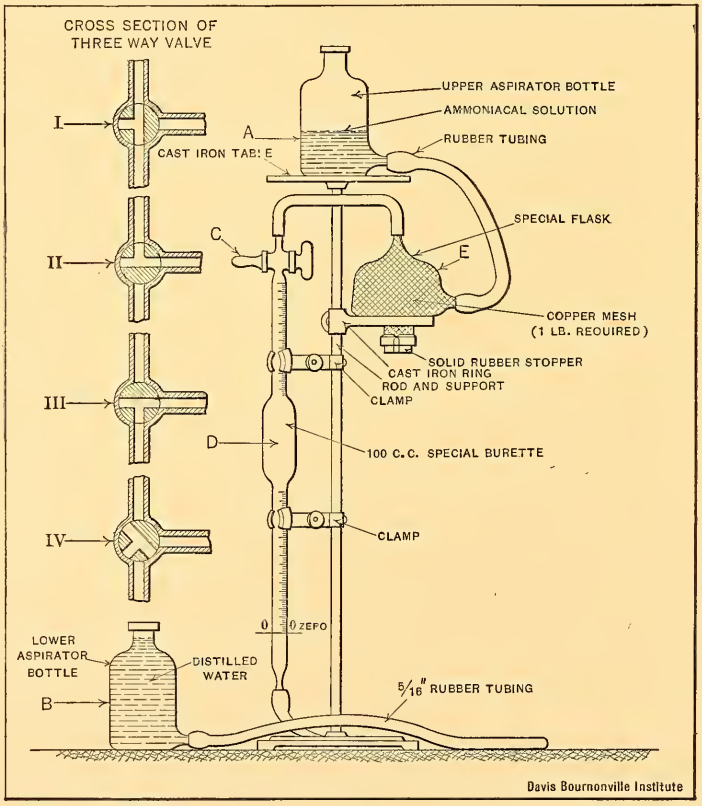

FIG. 4. APPARATUS FOR DETERMINING CHEMICAL PURITY OF OXYGEN

of commercial electrolytic cells has resulted only from a costly process of experimentation.

The illustration shows the Davis-Bournonville 1000-ampere electrolytic generator. This generator, which operates with a current of two volts and 1000 amperes generates or separates, theoretically, 7.92 cubic feet of oxygen and 15.84 cubic feet of hydrogen an hour. In some installations the hydrogen is not used and it is allowed to escape to the atmosphere. The oxygen is drawn off into a gasometer from which it is pumped with a water-cooled air compressor into cylinders or into a distributing pipe for use in the factory. If the hydrogen is also to be saved, it is also collected in a separate gasometer and pumped into cylinders or piped to the factory for use.

Inasmuch as hydrogen is somewhat more effective as a preheating gas in the cutting torch for cutting thick steel than acetylene it is obvious that the manufacturer, making considerable use of cutting torches, could advantageously provide the comparatively simple apparatus for manufacturing both gases required for cutting.

Pure Water Required for the Electrolyte

It will not do to use water drawn from the city mains for the electrolyte of the generator. Pure water must be provided. By this we mean distilled water which, by the process of distillation has been freed from earthly impurities, nitrates and other compounds that have an injurious effect on the electrolytic cell. But although we provide pure water we do not use it in the pure state for the reason that pure water is not a good conductor of electricity. In order to make the cell operate satisfactorily we must introduce into the water a chemical that increases its electric conductivity but which at the same time has no injurious effect on cell parts. Caustic soda has been found to work satisfactorily and it is used for this purpose. It has no injurious effect on the plates or containers and it remains in the water unchanged indefinitely. In short, a cell once charged with water and the proper proportion of caustic soda requires only the addition of dis-

tilled water from time to time, as the caustic soda is not used up.

The cells must be insulated and the pipes connecting them to the manifold are provided with short sections of hard

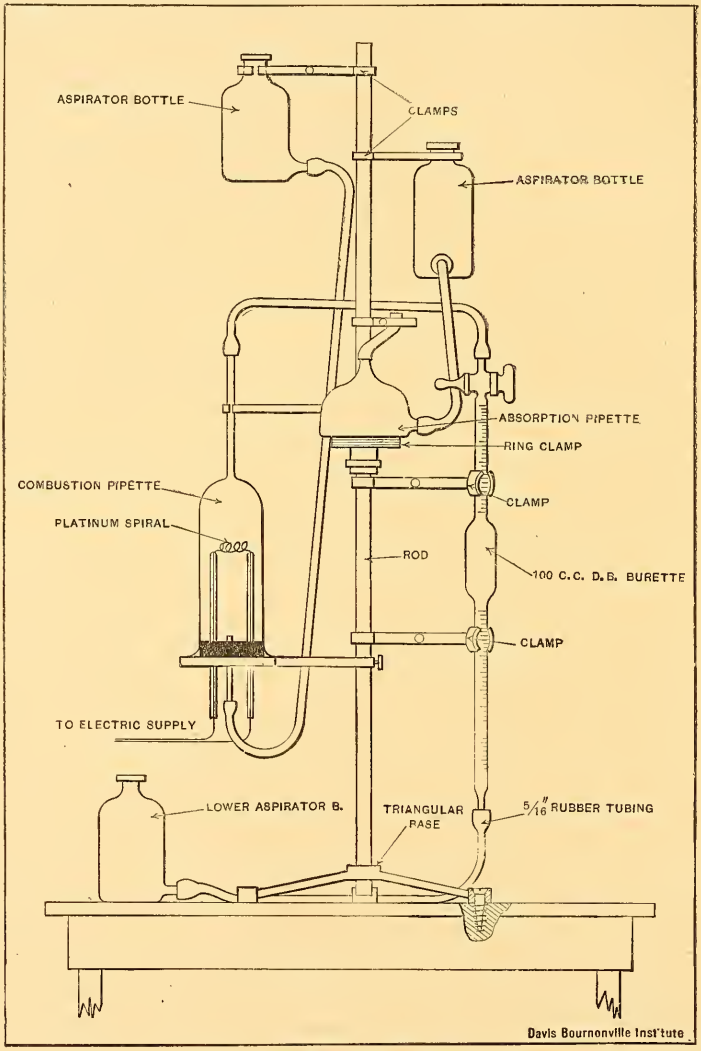

FIG. 5. APPARATUS FOR DETERMINING CHEMICAL PURITY OF HYDROGEN

rubber or rubber tubing interposed for insulating purposes. The matter of insulation and short circuits is highly important, and care must be taken that nothing is laid on the cells that might short circuit the bus bars. It is also important that the electrical connections are always kept tight and free from corrosion. The same remarks apply to the 500-ampere cell which is of the same design and construction as the 1000-ampere cell. The production of oxygen and hydrogen is just one-half of that produced hourly by the 1000-ampere cell.

Electrolytic cells are set up in batteries connected in series and in parallel depending on the number required to produce the quantity of gases needed. Suppose that a constant supply of 40 to 45 cubic feet of oxygen is needed hourly. Then six 1000-ampere cells will be required to produce the oxygen, if operated steadily. They should be connected in series, and as the voltage required for each cell is two volts, a voltage of 12 volts will be required to operate the six cells in series.

The apparatus required for operating an electrolytic gas generator is fully automatic in practice. The chief duties of an attendant are to supply the distilled water daily and to make an occasional sample test of the purity of the gas in order to be sure that everything is proceeding satisfactorily. The motor-generator operates on any commercial current, direct or alternating and generates the required low voltage direct current. The electrical apparatus stops and starts the gas compressor as the pressure falls and rises. If the oxygen is distributed through the building by a pipe line the compressor automatically maintains the pressure to which the controller is set. If the gases are to be bottled they are stored in a gasometer and pumped into cylinders at set intervals.

The distilled water should be supplied daily and in amount depending on the production of gases. Approximately, one gallon per 100 cubic foot of oxygen at atmospheric pressure is required. The oxygen generated by the electrolytic process has an average purity of 99½ per cent while the hydrogen—two times the volume of oxygen—is practically 100 per cent

or absolutely pure. The purity of the gas is a very important factor in the efficiency of the cutting torch; hence, electrolytic oxygen and hydrogen are most effective gases for the cutting torch.

Questions

1. About what proportion of the atmosphere is oxygen?
2. Is oxygen otherwise found in the free state?
3. What are the three principal methods of producing commercially pure oxygen?
4. Are chemical processes of producing oxygen now commercially profitable? Why?
5. Briefly, what is the liquid air process?
6. How is oxygen furnished to the trade?
7. What is the pressure in pounds to the square inch in an oxygen cylinder when received from the manufacturer?
8. What gases are produced by the electrolytic process?
9. From what is oxygen produced in the electrolytic process?
10. What is the oxygen capacity per hour of a 1,000 ampere Davis-Bournonville electrolytic generator?
11. Is it safe to distribute oxygen throughout a factory in iron pipe?
12. What precaution should be taken in regard to the use of oil and grease in oxygen apparatus? Why?
13. What is hydrogen used for chiefly?
14. What is likely to happen if oxygen cylinders are stored in a warm place near furnaces, boilers, etc.?
15. How should the cylinder stop valve be opened to prevent leakage around the valve stem?
16. Is it safe to let an oxygen cylinder stand beneath a line shaft or countershaft? Why?
17. What should be done with the valve protecting cap when the cylinder is returned to the manufacturer?
18. Is it safe to use an acetylene regulator on an oxygen pipe line?

Notes

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ACETYLENE AND ACETYLENE CYLINDERS

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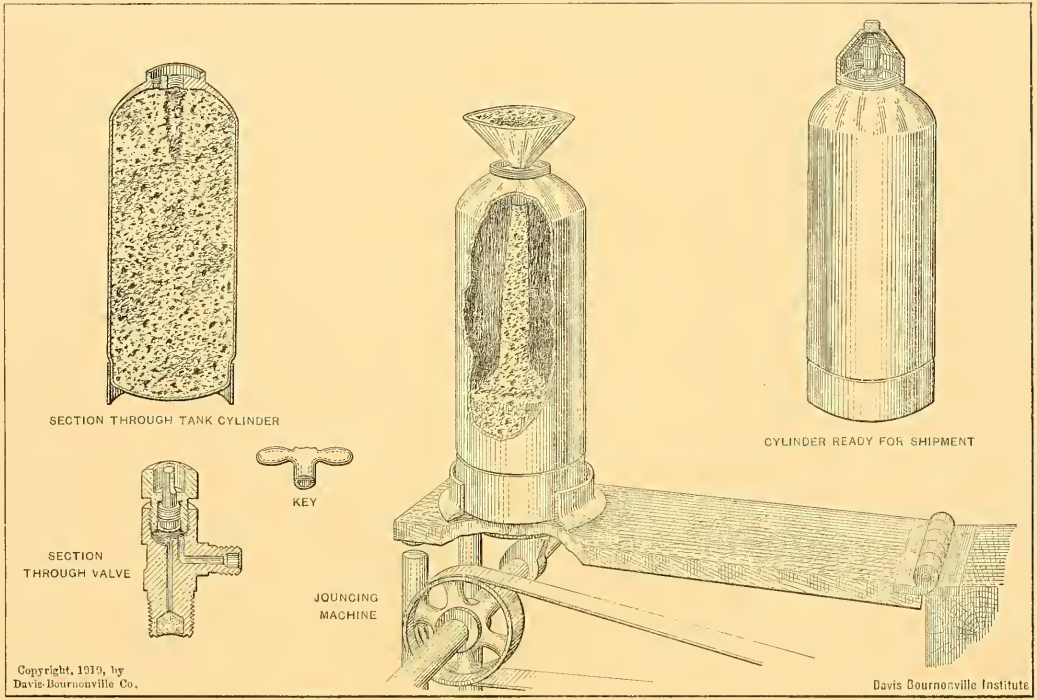

FIG. 1. ACETYLENE CYLINDER IN SECTION, SHOWING FILLING MATERIAL —CYLINDER STOP VALVE AND KEY—METHOD OF JARRING FILLING MATERIAL —CYLINDER READY FOR SHIPMENT

ACETYLENE AND ACETYLENE CYLINDERS

Acetylene from Calcium Carbide—Acetylene an Endothermic Compound—Acetylene Absorbed in Acetone—Construction of Acetylene Cylinders—Cylinder Stop Valve—Danger of Leaky Pipes and Connections—To Find the Amount of Acetylene Remaining in a Cylinder—Importance of Maintaining Acetone Content—Recharging Acetylene Cylinders—Care of Cylinder Stop Valves.

In 1892 Thomas L. Willson conducted an experiment at Spray, N. C., with an electric furnace for the purpose of producing metallic calcium. He subjected a mixture of coal, tar and lime to an electric current of 2000 amperes and 36 volts in a Héroult furnace. The temperature produced in the electric furnace is very high, and some chemical changes take place at high temperatures that are impossible at a lower temperature. Willson hoped that the re-action of the mixture subjected to the high temperature might produce metallic calcium. But he produced a substance of much greater value—although he was at first bitterly disappointed.

Acetylene from Calcium Carbide

When the furnace was opened it was found to contain a dark-colored mass which on cooling was solid and brittle. This clearly was not metallic calcium, and in disgust the Willson engineers broke it up and threw it into a nearby stream. Bubbles of gas were soon noticed rising from the fragments at the bottom of the stream, and someone applied a match to one of the bubbles as it escaped from the water. It burned with a bright but smoky flame—quite different from hydrogen flame or any other combustible gas that the world was then familiar with.

An analysis of the furnace product proved it to be calcium carbide. Calcium carbide was not unknown to chemists, but it had never before been produced in quantities nor was its great commercial possibility realized. The electric furnace made available a new product with which in a comparatively

simple apparatus, a gas of astonishing possibilities could be cheaply produced. Calcium carbide, like calcium oxide (quick lime), slakes in water. When calcium carbide is thrown into water it absorbs water and produces slaked lime and acetylene. The slaked lime settles to the bottom while the gas escapes from the water and passes off into the atmosphere or a suitable receptacle like a gasometer, where it is stored for use.

Acetylene an Endothermic Compound

Acetylene is carbon and hydrogen chemically united and is very rich in British heat units. In other words, it will produce a very hot flame when burned with the proper oxygen supply. It is the fuel used in the oxy-acetylene torch, and as has been stated in a previous lecture, the discovery of acetylene was a step in progress that made gas welding the

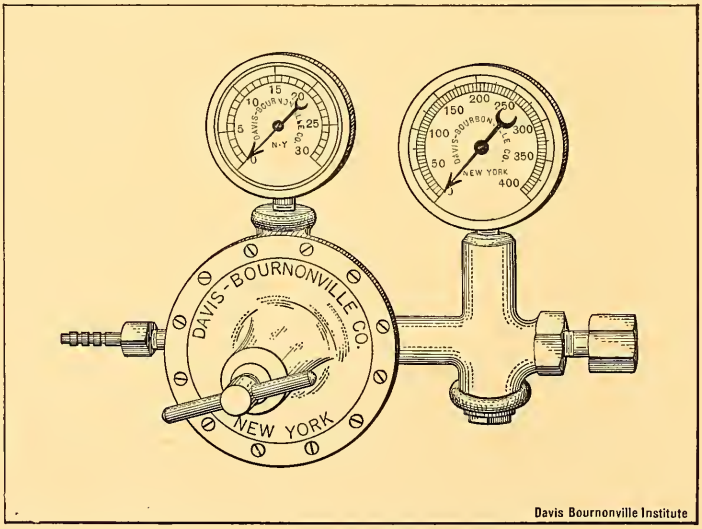

FIG. 2. ACETYLENE PRESSURE REGULATOR AND HIGH AND LOW PRESSURE GAUGES

important industry that it is today. It may be manufactured in an acetylene generator for use in the factory or it may be purchased, compressed into steel bottles the same as oxygen.

But unfortunately, acteylene cannot be as safely compressed in the same way as oxygen, hydrogen and other gases. It is what is called an endothermic or heat-absorbing substance, having the peculiarity of absorbing heat when it is generated. The atoms in the molecule are in an unstable condition and are likely to dissociate under heavy pressure, thus releasing molecular heat and causing an explosion.

Acetylene Absorbed in Acetone

This peculiarity of acetylene makes it dangerous to compress free acetylene to a pressure much more than 30 pounds to the square inch into an ordinary container. It is liable to explode, with disastrous results. However, we are able to accomplish, indirectly what cannot be done directly with safety. Acetylene dissolves freely in acetone. This product of wood distillation will absorb over twenty-four times its volume of acetylene at atmospheric pressure and ordinary temperature, and its absorptive capacity increases directly as the pressure rises. At two atmospheres pressure a given volume of acetone absorbs over forty-eight volumes of acetylene, and so on. Hence, we can dissolve our acetylene in acetone, and by compression force a large quantity into a small space.

But the acetone slightly increases in bulk as it absorbs acetylene, and as it gives the acetylene off it shrinks. This means that if we have an ordinary steel cylinder filled with acetone, containing dissolved acetylene at a pressure of say 225 pounds to the square inch, a safe condition would exist only while the full pressure of acetylene is maintained. As soon as any acetylene is drawn off the acetone shrinks and leaves a space at the top of the cylinder in which free acetylene will collect under heavy pressure. This immediately becomes dangerous and likely to explode from shock or even rapid discharge of the cylinder contents.

Construction of Acetylene Cylinders

The difficulty is overcome by filling the cylinder with a porous mixture consisting of charcoal, infusorial earth, as-

bestos and a small quantity of cement. This mixture though compacted until solid, is highly porous and capable of absorbing a large amount of acetone. The porosity is from 75 to 80 per cent of the total bulk. It is thus a sort of sponge for the liquid acetone. The cylinder is packed completely full, and slowly dried and baked. The air is then exhausted to about 9 pounds absolute and the cylinder is charged with acetone, which fills the pores. Then the acetylene may be pumped in safely to a pressure of 225 pounds per square inch or more, and discharged with equal safety. The porous filler completely fills the cylinder and there are no large spaces in which free acetylene can collect. So long as it is prevented from collecting in considerable volume in the free state no danger need be feared. The filler thus becomes a mineral sponge filled with a liquid sponge which absorbs the gas.

The illustrations show sectional views of a dissolved acetylene cylinder, and the principle of the filling apparatus. Great care must be taken to fill every part so that no settlement will take place while in use. The cylinder is jounced on a platform that is kept in rapid vibration while the filler is being put in. It is necessary to fill the cylinder completely up to and including the neck, which is no easy operation. Not a cubic inch should be left between the filler and the valve nipple. After the filler has hardened a hole is drilled into it and filled with an asbestos wick. This provides for drawing off the acetylene through a considerable size outlet from the filler.

The acetone gives up the acetylene readily when the pressure is reduced, and there is little tendency for it to go over with the escaping gas unless the rate of discharge is too high. If the acetylene is used too rapidly the acetone will also be drawn out with injurious effect on the welded joint. The escape of acetone can be quickly detected by the odor. No trouble will be experienced with escaping acetone in ordinary welding when using regular commercial cylinders provided the cylinders are kept in a vertical position. If necessary to lay the cylinders down they should be supported at an angle with the nozzle as high as possible.

Cylinder Stop Valve

The view at the lower left, Fig. 1, shows the construction of a stop valve used on one make of acetylene cylinders. It is quite different from that of an ordinary stop valve used for controlling pressures, and you should study it so that in case it is necessary to take one apart you can assemble it properly. The stem is round and flattened on one side. This makes the use of a special key necessary, and thus prevents tampering by unauthorized persons. The valve stem cannot be turned except with the key. The collar around it prevents the use of a pipe wrench.

The lower end of the stem sets in a shoe which rests on a stack of thin steel discs separated by a thin sheet steel ring. Beneath the discs is a perforated disc, containing five holes, four in a circle and one in the center. The holes in the circle are directly over a circular groove which is tapped by a hole leading to the outlet. When the stem is screwed down the discs are forced firmly together and the lower one seals the opening in the center of the perforated disc. Screwing the stem out releases the pressure on the discs and permit the gas to escape to the center hole beneath the discs down through the holes into the circular valve and out to the torch. A fine mesh wire screen or felt plug is provided beneath the cylinder stop valve to prevent scale, earth and other foreign matter being drawn out with the gas. Small particles of scale might lodge in the valve and prevent it being tightly closed when the gas is shut off.

The cylinder valve is double seated, the same as the oxygen cylinder valve, to prevent the gas leaking around the stem. The valve stem should therefore be opened full or as far as the stem can be turned, when in use. The upper seat then prevents the gas getting to the stem and leaking.

Danger of Leaky Pipes and Connections

Acetylene cylinders are provided with a safety plug which is screwed into the shell beside the stop valve. Its purpose is to relieve the contents in case of over-pressure.

If a cylinder is exposed to high temperature for a considerable period the pressure may run up to a dangerous point and the safety valve is required to relieve the pressure. Acetylene cylinders should never be stored near boilers or furnaces nor should they be left outdoors in the summer exposed to the hot rays of the sun. If the safety valve blows outdoors nothing worse is likely to happen than the loss of acetylene, but the blowing of the plug in a closed room near a furnace may cause a disastrous fire.

This brings up the matter of leaky pipes and connection, which could never be tolerated, as a leak in any acetylene apparatus may be a grave danger. An accumulation of acetylene in a closed room becomes highly explosive if the gas dilution is slightly in excess of 3 per cent. A spark produced by a nail in a shoe heel even may serve to ignite and cause an explosion of sufficient force to wreck a building and kill the occupants. No pains should be spared to prevent leaks, nor should there be any delay in stopping leaks that develop in service. Fortunately, acetylene has a peculiar and quickly recognized odor somewhat like garlic, which even in minute quantities is perceptible to any one with normal perception of odors. Explosions resulting from leaky acetylene pipes are rare because very few would continue to endure the odor long before the mixture has reached the dangerous or explosive stage. A great danger is incurred when entering a closed room with open lights if the air is contaminated with acetylene. Under no circumstances should a fire or any other open light be carried into any closed space where the odor of acetylene is very strong. It is hardly necessary to caution an intelligent person against the danger of exploring a leaky pipe with a torch or lighted match to find a leak. Use the senses of hearing and smelling to find the leak, or if it is minute apply soapsuds to the joints with a brush and watch to see bubbles form.

To Find the Amount of Acetylene Remaining in a Cylinder

Because the gas in an acetylene cylinder is dissolved in acetone the pressure gauge is not an indication of the amount

of gas remaining. The pressure indicated in an oxygen or hydrogen cylinders tells you how much gas remains, but not so in an acetylene cylinder. The way to tell how much acetylene remains is to clean off the cylinder and weigh it on accurate scales. Compare the weight with the weight stamped on the name plate. The difference is the weight of the acetylene contained, provided the acetone content is up to the standard. Acetylene under atmospheric pressure and normal temperature is rated commercially at 14½ cubic feet per pound. Suppose that the cylinder is found to weigh 211 pounds and the stamped weight is 207 pounds, then the difference or four pounds should be the weight of the dissolved acetylene. Multiplying 14½ by 4 gives 58 cubic feet, the amount of gas still remaining.

Importance of Maintaining Acetone Content

If acetylene is discharged rapidly from an acetylene cylinder, the acetone is drawn out also because of the rapid bubbling of gas and consequent vaporization of the liquid. The rule is to never draw from an acetylene cylinder at a rate of more than one-seventh of the capacity in cubic feet per hour. Suppose that the rated capacity of an acetylene cylinder is 225 cubic feet. Then the maximum hourly rate of gas consumption should not exceed 32 cubic feet. The No. 7 tip, if used continuously, is rated at 33 cubic feet acetylene consumption, or slightly more than one-seventh of the rated capacity of the 225-cubic foot cylinder. However, the cylinder should not be overtaxed to supply a No. 7 tip in ordinary welding usually as the use of gas is almost always intermittent.

Recharging Acetylene Cylinders

Inasmuch as there is always uncertainty as to the acetone content when a cylinder is returned to the recharging station it should be weighed and the acetone content checked up. If below weight sufficient acetone should be injected to bring the weight up to the standard. Then the cylinder may be recharged safely to the standard pressure, but not otherwise.

If the acetone content is not standardized there is no way of knowing how much acetylene can be safely charged into the cylinder. If a cylinder is returned to the charging station containing 40 or 50 pounds pressure, it will be necessary to discharge the gas into a gasometer before testing the weight.

If the charging station is connected with a manufacturing plant, however, and the man in charge keeps an accurate record of all the cylinders in his care he may ignore the rule to recharge and weigh all cylinders at every recharging, provided he knows the conditions of use and makes it an invariable rule to test periodically, say at every fifth or sixth charging. If this procedure is followed each cylinder should be tested with the pressure gauge and the pressure chalked on each cylinder. Then when connected to the manifold for recharging the following order should be observed in opening the charging valves. Suppose that four cylinders are to be charged and that the tests show pressures remaining of 15, 25, 38 and 45 pounds. These numbers are chalked on the respective cylinders. When the compressor is started the cylinder marked 15 is charged first and the stop valve of the cylinder containing 25 pounds pressure is opened only when the compressor gauge shows 25 pounds pressure. This order should be observed throughout. The reason for it is to prevent the cylinders containing comparatively high pressures charging back into the cylinders containing gas at low pressures at so rapid a rate that the acetone is drawn over.

Care of Cylinder Stop Valves

The cylinder stop valves on acetylene and oxygen cylinders are protected in transit by rail with a metal cap or shield that screws over the end of the cylinder nozzle, covers the valve and prevents it being broken off. The welder should always replace the valve protectors when transporting acetylene cylinders and oxygen cylinders to field jobs or even if he is moving them from one part of the plant to another. It is, of course, necessary to remove the regulators before the cap can be screwed in place. But this is always advisable when cylinders are being shifted on a truck. A regulator is easily

broken and no chances should be taken to save the few minutes required to unscrew the connections and replace it when setting up again.

Questions

1. When was acetylene commercially discovered?
2. In view of the fact that acetylene had long been known, why was this a commercial discovery?
3. How is acetylene generated?
4. By what process is calcium carbide manufactured?
5. Is it safe to compress acetylene to a pressure of more than 30 pounds? Why?
6. What is the recommended safe pressure?
7. What is acetylene composed of?
8. How is acetylene safely compressed to 225 pounds per square inch?
9. What is the chief characteristic of the filler used in acetylene cylinders?
10. What is the liquid used to dissolve the acetylene?
11. What happens if you use acetylene too rapidly?
12. Is acetone injurious when welding?
13. Can you determine how much acetylene remains in a cylinder by weighing it?
14. How many cubic feet in one pound of acetylene at atmospheric pressure?

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DAVIS-BOURNONVILLE
OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

ACETYLENE GENERATORS

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

Form 383

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ACETYLENE GENERATORS

Commercial Acetylene Generators—Generator Types—Principal Requirements of Generators—Davis-Bournonville 200-Pound and 300-Pound Generators—Acetylene Generator House—Directions for Charging—Rules for Recharging—Safety Rules.

The generation of acetylene from calcium carbide is very simple, in fact, so simple that it was discovered by accident; and the experiment can be made by anyone having a lump of calcium carbide and a glass of water. Drop the carbide into water and immediately bubbles of gas begin to rise which, if ignited, burn with a red, smoky flame as they come to the surface. That, you may know, is what happened when Willson undertook to produce metallic calcium in 1892, but obtained calcium carbide instead. The rejected mass resulting from the failure produced an unknown gas when thrown into a nearby stream. Someone with an investigating spirit, undaunted in the face of apparent failure, discovered that a new means of producing a combustible gas had been created.

Commercial Acetylene Generators

While it is true that the apparatus needed for the laboratory experiment to make acetylene is very simple, the commercial generation of acetylene is far from being a simple matter. In the first place, acetylene is a good servant but a bad master. Under normal conditions it performs beautifully, but if mishandled the results may be disastrous.

The apparatus required for the commercial generation of acetylene should be efficient, safe and automatic in operation and convenient to take care of. Such generators are available, but they were developed only after much experimenting and costly mistakes. There are, available today acetylene generators that require so little attention that they are practically automatic and so safe that there is little difficulty in getting permission to use them for factories in towns and cities.

Generator Types

There are two systems or types of generators, differentiated chiefly by the manner in which the water and carbide are brought together. One called the water-to-carbide type, is that in which the water is applied to the carbide by sprinkling or injection. The other and principal type of acetylene generator is the carbide-to-water type, in which a comparatively large body of water is provided and means for dropping the carbide into the water automatically and in amounts determined by the consumption. The carbide-to-water type of generator has certain advantages that recommend it to users in general as well as safety engineers and insurance companies. A large volume of water is provided in this type to absorb the heat produced when the carbide slakes and gives off gas. The water "drowns" the carbide and prevents the temperature rising to a dangerous point. It is obvious that as long as the carbide is under water the temperature cannot rise above the boiling point or 212 degrees F. Cool generation is an imperative requisite for safe and efficient generation.

Acetylene is an endothermic compound and is liable to so-called spontaneous explosion under certain conditions such as high compression, overheating, the presence of impurities, sudden shock, etc. The subject of safety, therefore, looms large in the consideration of an acetylene generator, and it is desirable to outline the principal requirements of a generator that meets the insurance requirements as well as the requirements of the commercial users.

Principal Requirements of Generator

1. It should provide for automatic generation of gas, and at no time should the temperature rise above the boiling point of water.
2. A safe generator should produce at no time an explosive mixture of acetylene and air.
3. It should be so constructed as to be positive in operation and should be well built of lasting materials.

4. The mechanism should be simple and not likely to get out of order. Generators are required to work automatically and are likely to be attended by unskilled labor. They should, therefore, be absolutely

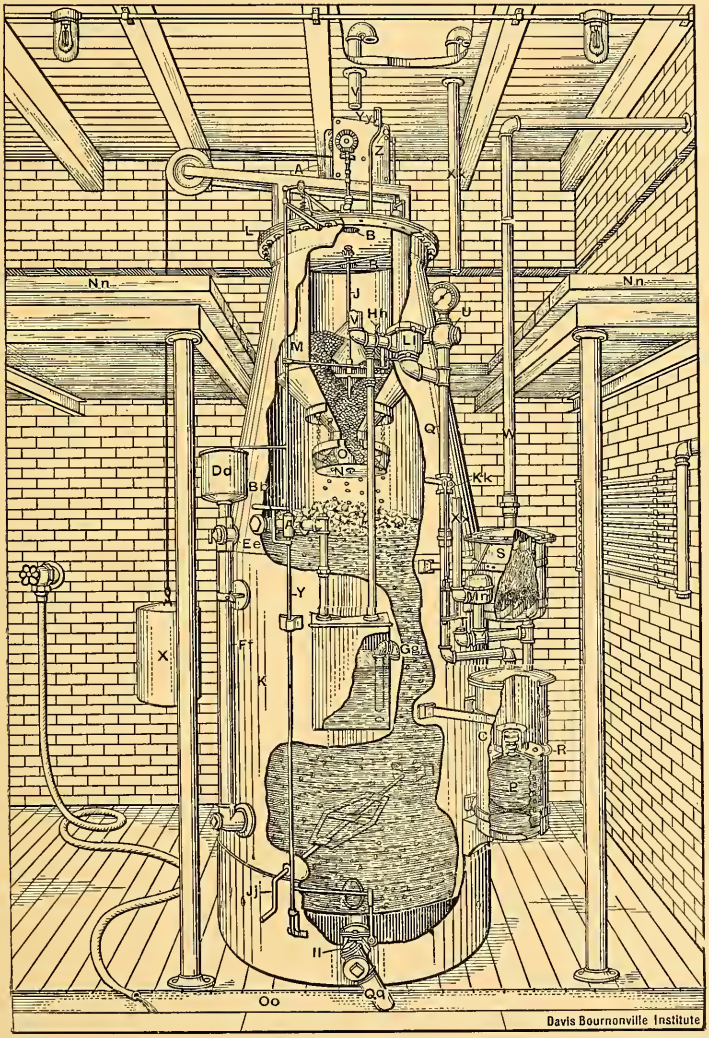

FIG. 1. DAVIS-BOURNONVILLE NO. 200 (AND NO. 300) ACETYLENE GENERATOR

reliable and easily understood by men of limited mechanical knowledge.

5. The insurance underwriters require that acetylene generators must operate with a comparatively low pressure. The pressure should never exceed 20 pounds per square inch, and in general should be somewhat less than 15 pounds.
6. The generator should be so constructed that it is easily cleaned and recharged. The construction should be such that little gas escapes when cleaning and recharging, and no explosive mixture is produced when it is again started into operation.
7. Safety devices should be provided to prevent overpressure.

Davis-Bournonville 200-Pound and 300-Pound Generators

The illustration shows the construction of the Davis-Bournonville acetylene generator of the 200-pound and 300-pound sizes. It is of the carbide-to-water type, a large reservoir for water being provided in the base and a weight motor for feeding the calcium carbide automatically to the water, as required. The carbide falls from the hopper upon a rotating feeding disc from which it is slowly scraped off to fall into the water beneath. The operation of the feed mechanism is controlled by the pressure of acetylene in the generator. When acetylene is being generated faster than it is used the pressure rises, and when it has reached a certain limit—generally 10 to 12 pounds maximum for welding and cutting—the operation of the motor is stopped and the rotation of the feeding disc ceases.

The carbide sinks to the bottom and slakes, giving off acetylene which bubbles to the top and finally escapes through the backfire valve and filter to the outlet service pipe. The capacity rating of the Davis-Bournonville generators is expressed by a number. The No. 200 generator holds 200 pounds of calcium carbide in the hopper and generates 200 cubic feet of acetylene hourly. The water reservoir contains 200 gallons,

thus providing one gallon per pound of carbide. On the basis of 4½ cubic feet of acetylene generated from one pound of carbide, the No. 200 generator will produce 900 cubic feet of gas at atmospheric pressure from one charging.

The motor is driven by the weight X acting through the cable upon the drum of the motor A. An interference clutch or stop checks the motor when the pressure runs too high, being operated by a feed controlling diaphragm. The calcium carbide is stored in the hopper from which it drops to the feeding disc N. To prevent clogging and stoppage a floating displacer ring O is provided. This is suspended so that it is free to swing to one side or the other in case a lump of carbide too large to pass through the feed mechanism falls upon the feeding disc.

The spent carbide or residuum collects in the bottom of the reservoir in a compact, sticky mass which requires breaking up and agitating in order to discharge it to the lime pit when recharging the generator. An agitator operated by a crank outside the shell is provided for the purpose. The mass of water and lime stirred up with the agitator runs off to the pit when the connection valve is opened. One of the rules never to be broken is to discharge the slaked carbide from the generator at each recharging. If the residuum is allowed to remain it reduces the water capacity and may cause overheating and polymerization. The development of polymers is injurious to the acetylene and it reduces the amount generated from the carbide. Polymerization is indicated by the presence of yellow tarry deposits on the residuum.

In case of over-pressure developing the gas blows off and escapes through the vent pipe V to the atmosphere. The vent pipe is connected to the water seal or trap on the side of the generator. This trap fills a double function. It provides for the overflow of water from the generator when recharging. The reservoir cannot be filled above the level of the out-flow pipe. The second function is to give warning of stoppage in the vent pipe should one occur. The gas escaping through the blow-off valve then forces the water seal and escapes. The odor of acetylene prevading the premises gives notice that something is wrong.

Generator Parts

A. Motor drum for weight cable.
B. Carbide filling plugs.
C. Backfire or flashback chamber.
D. Emergency locking collars.
E. Lever on feed controlling diaphragm valve.
F. Lever of emergency diaphragm valve, which operates emergency locking collars D.
G. Feed controlling diaphragm valve.
H. Emergency diaphragm valve.
J. Main shaft driving carbide feed disc.
K. Generator shell.
L. Generator top plate.
M. Carbide hopper.
N. Carbide feed disc.
O. Carbide displacer ring.
P. Backfire or flashback chamber valve and float.
Q. Outlet pipe to backfire or flashback chamber.
R. Overflow plug of backfire or flashback chamber.
S. Filter.
T. Water filling pipe for backfire or flashback chamber.
U. Pressure gauge bushing.
V. Blow-off pipe.
W. Outlet pipe to gas service line from generator.
X. Operating weight.
Y. Vertical controlling rod.
Z. Motor locking thumb pin.
Aa. Vent valve.
Bb. Handle of vertical controlling rod.
Dd. Water filling funnel.
Ee. Valve in water filling pipe.
Ff. Water filling pipe of generator.
Gg. Overflow pipe of drainage chamber.
Hh. Lever of blow-off valve.
Ii. Residuum discharge valve.
Jj. Handle of agitator.
Kk. Valve in outlet pipe to backfire or flashback chamber.

Ll. Generator blow-off valve.
Mm. Backfire chamber blow-off valve.
Nn. Charging platform.
Oo. Residuum gutter.
Qq. Residuum discharge pipe.

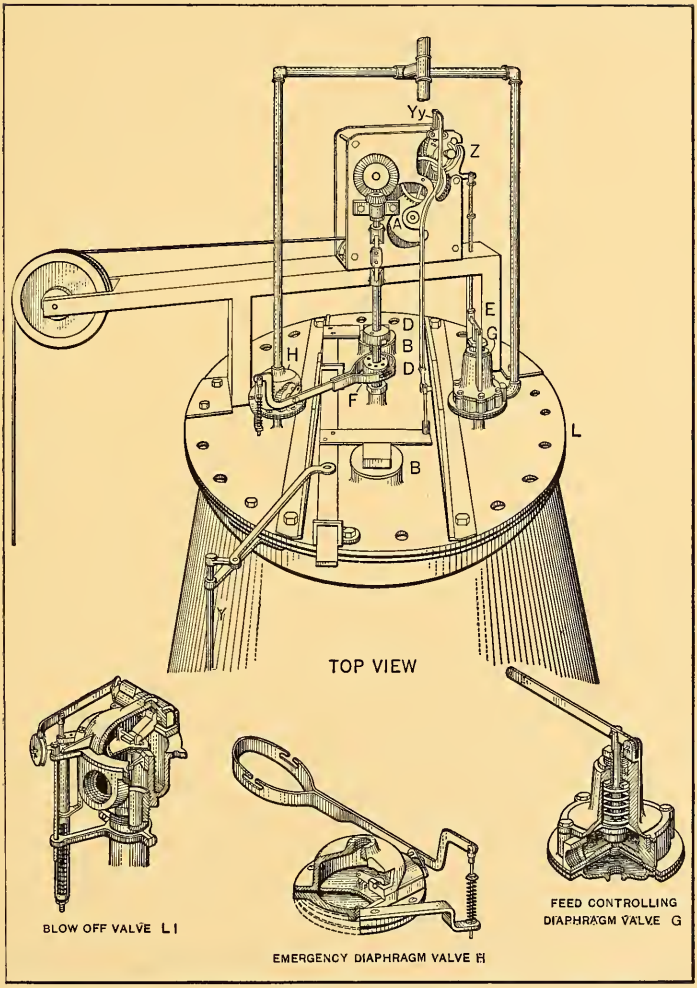

FIG. 2. TOP OF DAVIS-BOURNONVILLE NO. 200 (AND NO. 300) SHOWING MOTOR AND CONTROL VALVES

Xx. Blow-off pipe from flashback.
Yy. Motor interference pin.

Acetylene Generator House

Acetylene generators may be placed within an isolated building, preferably of fireproof construction. It should be located away from boilers, furnaces, railway tracks or any source of fire or sparks. The fact should be recognized that an acetylene generator is used to produce an inflammable gas which, mixed with air, becomes highly explosive and dangerous. A generator may be placed within a building used for other purposes provided it is isolated by partitions and the room is vented to draw off any accumulation of gas. Preferably the generator room should be so located that artificial heat will not be required in the winter to prevent the water from freezing. But if this is not feasible a steam coil or radiator may be provided for use in extremely cold weather. While it is true that a generator in use is not likely to freeze because of the heat produced in generation, no chances should be taken of a generator freezing when not in use as the result may be serious.

Inasmuch as the conditions are generally such that the residuum cannot be discharged into the sewer it will be necessary to provide a pit adjacent to the generator house into which it can be deposited. In some localities the slaked lime has commercial value and can be sold at a price sufficient to pay a profit on the cost of handling and selling.

Open lights should never be used in an acetylene generator house. Incandescent lights should be provided, but all switches should be placed outside. The light bulbs should be protected by gas-tight glass. Incandescent bulbs attached to flexible cables provided with wire protectors may be used for examining the generator when absolutely necessary. The use of such lights, however, should be limited to emergencies, as there is always danger of short circuits, broken bulbs or other accidents that might cause ignition of inflammable gas.

Copper pipe or tubing should never be used for an acetylene pipe line, as the acetylene may, under favorable condi-

tions form copper acetylide, which is an explosive compound. Brass (which contains copper) is not so affected except when in contact with the sludge formed in an acetylene generator. No brass parts should be used in a generator that make contact with the water. Brass parts in the generator above the water exposed only to the gas itself are not likely to be affected.

Directions for Charging

1. Close the vent valve Aa by turning the handle Bb to the left as far as it will go. This releases the motor interference pin Yy.
2. Release the motor by means of the motor locking thumb pin Z and raise the lever on the feed controlling diaphragm valve, thus allowing the weight to descend a short distance in order to determine whether the motor is operating properly. Then rewind to the full height and lock with the motor locking pin.
3. Open the vent valve Aa by turning the handle Bb to the right as far as it will go.
4. Close the residuum valve Ii.
5. Open the water filling valve Ee.
6. Close the valve Kk in the outlet pipe to the flashback or backfire chamber.
7. Remove the out-flow plug R from the flashback chamber C and the plug from the water filling pipe T. Fill with water at the lower opening until it overflows at R and then replace both plugs tightly.
8. Fill the generator with water through the funnel Dd until it overflows at Gg, then close the valve Ee.
9. Remove the carbide filling plugs B and fill the hopper with 1¼-inch by ⅜-inch carbide (nut size). Replace the carbide filling plugs tightly.
10. Close the vent valve Aa by turning the handle Bb to the left as far as it will go.
11. Unlock the motor thumb pin Z.
12. Raise the feed control diaphragm lever, allowing the motor to run until the valve shows about 5 pounds

pressure. Then raise the lever Hh of the blow-off valve Ll and discharge the gas until the pressure has dropped to 2 pounds. This is done to remove all air from the generator and avoid producing an explosive mixture of air and acetylene. Again raise the feed control diaphragm lever and permit the generator to operate until the gauge shows 8 pounds pressure, after which the motor will operate automatically as the gas is consumed.

13. When ready to use acetylene, open the valve Kk slowly and thus admit the acetylene to the service pipe through the backfire chamber and filter.

Rules for Recharging

The rules for recharging the generator differ somewhat from those for charging and starting, as follows:

1. Close the valve Kk in the outlet pipe to the backfire or flashback chamber.
2. Close the vent valve handle Bb to the right as far as it will go.
3. Revolve the agitator handle Jj several times.
4. Open the residuum discharge valve Ii and draw off all the water and sludge, after which the valve should be closed.
5. Open the water inlet valve Ee thereafter, fill the generator with water. Revolve the agitator again and draw off all water and sludge as before.
6. Having closed the valve Ii, fill the generator with water at the funnel Dd until it overflows at Gg. (It is desirable when filling to let the water run in as rapidly as possible in order to keep the filling pipe full and thus prevent air entering the chamber at the same time.)
7. Close the valve Ee in the water filling pipe.
8. Rewind the motor and lock it with the motor locking thumb pin Z.
9. Remove the carbide filling plugs B and fill the hopper with 1¼-inch by ⅜-inch carbide (nut size).

Replace the filling plugs.

10. Close the vent valve Aa by turning the handle Bb to the left as far as it will go.
11. Unlock the motor thumb pin Z.
12. Raise the feed controlling diaphragm lever, allowing the motor to run until the gauge shows about 5 pounds pressure. Then raise the lever Hh of the blow-off valve Ll and discharge the gas through the vent pipe until the pressure has dropped to 2 pounds. This is done to remove all air from the generator. Again raise the feed control diaphragm lever until the gauge shows 8 pounds pressure, after which the motor will operate automatically as the gas is consumed.
13. When ready to use the acetylene, slowly open the valve Kk.

Safety Rules

1. Remember that an acetylene generator produces inflammable gas and that all precautions should be taken to prevent the escape of gas through careless handling of apparatus, leaks, etc.
2. Do not carry or permit lighted pipes or cigars or open fires of any kind within a generator house or room.
3. Always remove all the residuum that is clogged in the bottom of the generator and fill with fresh water before recharging. Neglect of this rule may cause the generator to be seriously overheated. In such an event do not open the generator until it has cooled down, as the admission of air to the heated gas may cause trouble. If through neglect a generator becomes overheated stop its operation and play a water hose upon it until it has cooled down.
4. Make sure that all the joints and pipes are tight before operating the generator. Joints may be tested for leaks by applying soap suds with a brush. Never use a light for the purpose.

5. Never force carbide into the filling openings or funnel with a metal rod.
6. Always discharge the air mixture from the generator each time it is recharged, as is directed in Rule 12.
7. After recharging the generator discharge all the air mixture from the pipe system before lighting torches. A back pressure valve should be provided in the pipe system, however, to prevent the escape of acetylene when recharging and thus making this precaution unnecessary.
8. The operating weights fall a certain distance in discharging the carbide charge in the hopper. If the operator notes the position of the driving weight when a full charge has been fed to the generator he will know thereafter when the charge is nearly exhausted by merely noting the position of the weight.
9. When making repairs to the generator always remove the carbide hopper and fill the shell completely full of water before applying a welding torch or soldering iron. Repairs of this nature should not be made in a generator house if there are any other generators in the same house.
10. The generator is designed to operate at a pressure from 10 to 12 pounds and the blow-off valve to operate at a pressure of 15 pounds. If for any reason the blow-off valve should fail the emergency diaphragm valve will raise a lever and thereby engage an emergency locking collar, thus stopping the motor. The motor cannot be operated again until the gas pressure has been reduced and the cause for the excess pressure found and removed. It should be understood, however, that the emergency diaphragm valve is designed only for operation in an emergency and that it is not likely to go into action in the ordinary operation of the generator.
11. The flashback or backfire chamber C must be kept filled with water at all times up to the level of the overflow plug R.

12. Care should be taken when charging a generator that no foreign substance is mixed with the carbide. A piece of brass or copper getting into the generator may cause trouble.

The generator thus provides for automatic gas production, it limits the pressure produced and is provided with safety devices which prevent careless and dangerous practice in charging. Of course, no apparatus can be made foolproof. Common sense is required of the one who takes care of a gas generator as much as of one who attends a heating furnace. If the rules are followed no trouble should be feared.

Questions

1. How is acetylene produced?
2. What are the principal types of generators?
3. Which is the best type? Why?
4. How are generators rated?
5. Why is a large water capacity desirable in an acetylene generator?
6. What is the rule for water capacity in an acetylene generator?
7. What precaution should be taken in regard to open lights when working around a generator?
8. Is it safe to use an incandescent lamp? If so, how should it be guarded?
9. What is the function of the clockwork motor?
10. What should be done with the residuum before recharging?
11. What is the danger of leaving the residuum in the generator?
12. What should be done when a leak develops?
13. How would you proceed to find a leak?
14. What happens if the vent valve becomes obstructed?

DAVIS-BOURNONVILLE
OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

OXY-ACETYLENE WELDING

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

Form 384

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OXY-ACETYLENE WELDING

What Welding is—Importance of Correct Torch Movement—Importance of Holding Welding Torch and Welding Rod in Proper Relation and Position—Desirable Characteristics of Welders—Classes of Welding—Grading Steels with the Emery Wheel—Learn to Estimate Costs—Safety Considerations.

We have lectured about combustion, structure of flame, heat and temperature, controlling gas supply, the oxy-acetylene welding torch, and several other matters closely pertaining to oxy-acetylene torch practice, and you have done some welding and are beginning to comprehend the possibilities as well as the difficulties of the art. We will, therefore, talk today about welding in the light of your experience. The work you have done in the past few days has helped, no doubt, to make clear some of the things that we have harped on but which you did not, perhaps, fully comprehend. The fact is that a full knowledge of oxy-acetylene torch practice requires a knowledge of so many things that it is somewhat difficult to start at any really logical place and tell you about it. About the best we can do is start you at welding and then tell you about the principles as you learn. When you are able to apply more or less successfully the principles of welding you are more interested in everything that makes for progress.

What Welding Is

In the first lecture on combustion, welding was defined as a process of uniting metals by fusing or partly melting the parts to be joined which then flow together and become one. That is the foundation of oxy-acetylene welding. You must fuse the edges of the plates you wish to join, and let the fused metal run together. You do not force the metal together; it runs together of its own accord when properly fused. The success of the welder depends on how well he fuses the metal and how systematically and intelligently he goes at his work. It will not do to fuse the metal with a

carbonizing or oxidizing flame; it must be done in a neutral flame in order to prevent injuring the metal and making a poor joint. You must learn to make welds with as little deterioration of the physical structure as possible. Remember that welds can be made having 90 to 95 per cent the strength of the unwelded steel.

The expert welder must be able to weld cast iron, steel, bronze and aluminum; he should be able to braze all the metals including copper, brass, malleable iron and other metals that may be brazed more effectively than welded, sometimes. He must be able to make the castings ready for welding,

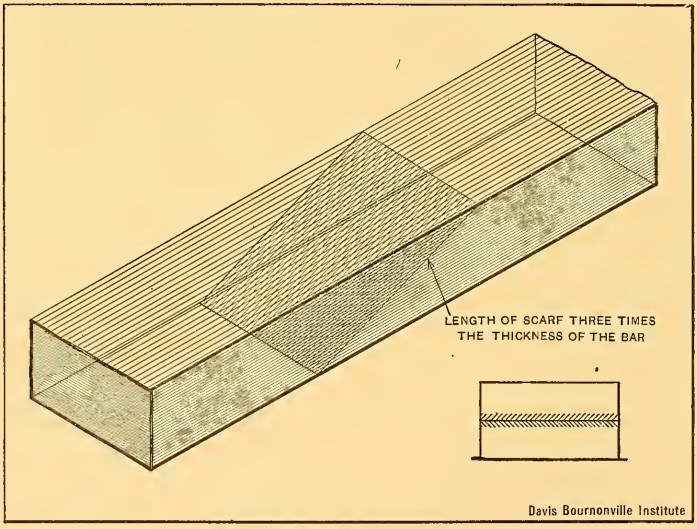

FIG. 1. SCARFED JOINT WELD MADE BY THE BLACKSMITH

bevel the joints, adjust them for alignment and preheat them so as to avoid destructive stress on the welded joint after the job is done.

Importance of Correct Torch Movement

The welder must go through a course of training that develops manual skill. He has to learn to hold the torch unconsciously with the tip of the white hot cone from an eighth to three-sixteenths inch above the puddle and at the same time

give the torch a motion across the joint that will distribute the heat to the best advantage. On prepared joints the welder is instructed to give the torch a sort of semicircular zig-zag movement. The reason for the semicircular instead of the plain zig-zag movement is that the flame dwells longer on the margins of the joint where heat must be supplied to compensate for that lost by conduction and where it is generally difficult to obtain sufficient temperature to insure perfect fusion and penetration. If the torch tip is given the simple straight zig-zag movement the flame will dwell only momen-

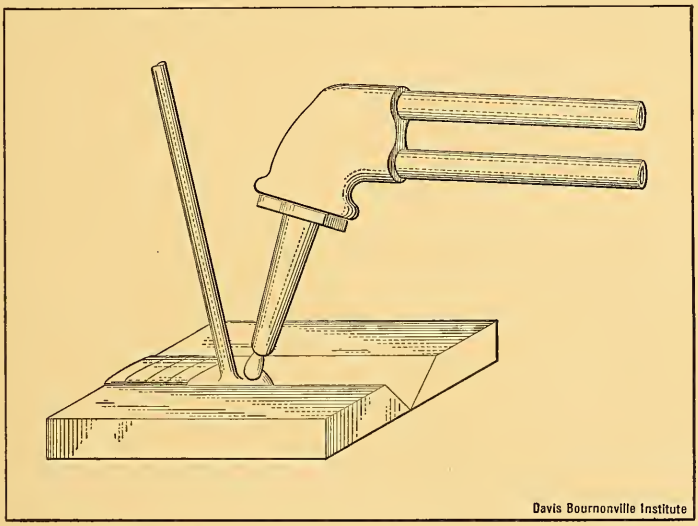

FIG. 2. TORCH HANDLE HELD PARALLEL TO JOINT. INCORRECT

tarily on the margins. Consequently, the metal will remain comparatively cool, and lapping and cold-shuts will likely be produced. If, however, the tip is given a semicircular movement the flame is concentrated for a considerably longer time on the margins of the joint and sufficient heat is thereby imparted to produce fusion and union.

Importance of Holding Welding Rod and Welding Torch in Correct Relation and Position

The accompanying illustrations, Figs. 2, 3, 4 and 5, show some of the errors to be avoided in welding as regards the

direction of welding, position of torch and the melting of the adding material. Fig. 6 shows the correct position of the torch in relation to the joint and the angle made by the tip with the surface of the metal. It also shows the correct direction of welding a prepared joint and the proper way to hold the welding rod. Prepared joints should be welded from left to right with the torch handle held at right angles to the joint and the head inclined to the right to an angle of about 50 degrees. The welding rod should be held in the left hand, and the white hot cone of the flame should never be used to melt the rod. It must take its heat from the puddle

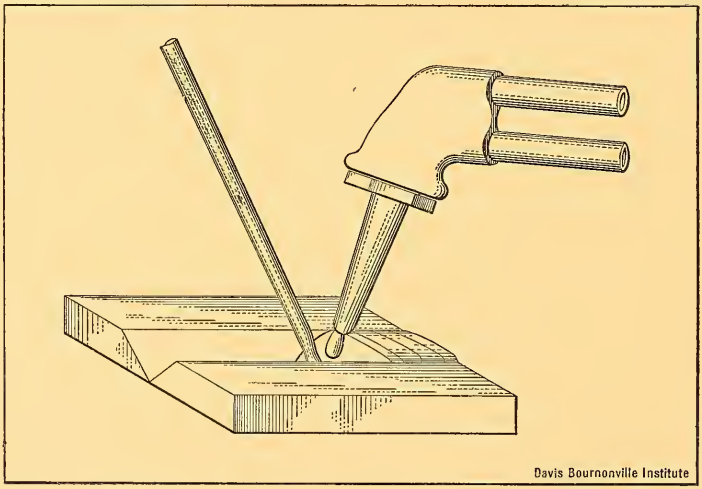

FIG. 3. WELDING FROM RIGHT TO LEFT IN A PREPARED JOINT. INCORRECT

as that is the only way the welder can make sure that he is imparting the necessary heat to obtain penetration.

Fig. 2 shows correct practice as regards the direction of welding and the manner of manipulating the welding rod but the torch handle is held approximately parallel to the joint. This is an awkward constrained position for the welder to assume, and should never be permitted except when the surroundings make it necessary. Fig. 3 shows welding from right to left in a prepared joint. It illustrates the disad-

vantage at which the flame operates on the declivity of the weld. The flame is not directed squarely against the side of the weld and lapping is likely to result. Moreover, there is danger of overheating the bottom of the vee and blowing a hole through. The torch should always be held in relation to the direction of welding so that the flame is directed more or less squarely against the declivity formed by the joint material. A left-handed welder may logically weld from right to left in a prepared joint as he will hold the torch in the left hand and the welding rod in the right.

Fig. 4 shows welding proceeding correctly from left to right in a prepared joint but the torch head is inclined to the left so that the flame is not directed squarely against the

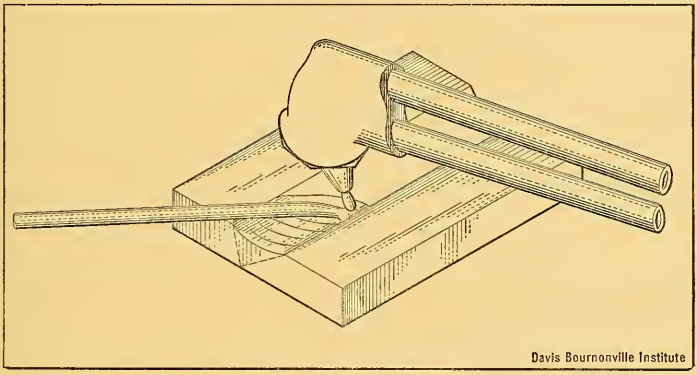

FIG. 4. TORCH HEAD INCLINED TO LEFT. INCORRECT

weld declivity and hence, the same fault is developed as in welding from right to left in Fig. 3. The welder must hold the torch at the proper angle to develop the best results from the flame. To do otherwise is to waste gas and to invite poor results.

You have been repeatedly warned not to fuse the adding material directly with the torch flame. Fig. 5 shows this error as it would appear to one standing in front of the weld being made by a left-handed operator. It is obvious from this illustration that the flame is not being directed where it should be to produce a puddle of molten metal that will blend perfectly with the parent metal. The welder

is more intent on fusing the welding rod and seeing the drops fall. The invariable results of such practice are cold-shuts, laps and weak welds.

Desirable Characteristics of Welders

The welder should be an all-around type of man who combines good common sense, judgment and manual skill and who is not afraid to work. It is not sufficient that he should be able to weld the casting so that when finished the parts will be in line and the shape will be nearly the same as before. If the welded casting is so distorted after welding

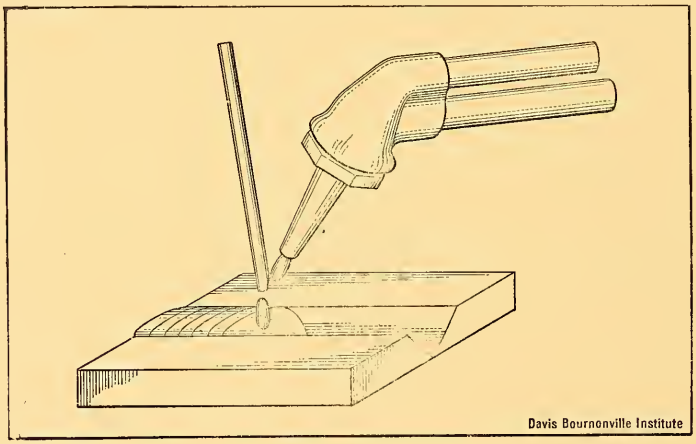

FIG. 5. MELTING ADDING MATERIAL WITH DIRECT FLAME. BAD PRACTICE

that it cannot be used or is an eye-sore, the job is a failure no matter how strongly the joint may be made. He must be able to choose the proper adding material, and use it economically; he should also recognize at a glance when flux should be used and what kind will yield the best result. If the welder is able to do good sound work, he should be able to tell bad work no matter how skillfully it may be camouflaged. But avoid knocking. Be generous and give others the credit due them. The knocker hurts himself and the booster helps every one, himself included.

We have not, heretofore, said much about preparing joints for welding nor have we discussed preheating. Both these subjects will be taken up later in detail. We will mention them here in order that you can get an idea of the manifold requirements of a successful welder. He must not only be able to weld but he must be able to prepare for welding, line up on floors or surface plates, build up temporary preheating furnaces, apply the heat where it will be most effective, protect parts that might be injured by overheating, learn to do his own rigging; in short he should be a master of his trade, able to handle a wide variety of repair work in a workmanlike manner.

Classes of Welding

Oxy-acetylene repair welding is divided into two general classes, shop work and field work. Repair work that can be carried to the workshop is, of course, taken where the appliances are at hand for lining up and preheating. Work that can be taken to the workshop, lined up on the bench or floor and welded, generally presents less difficulties than that which

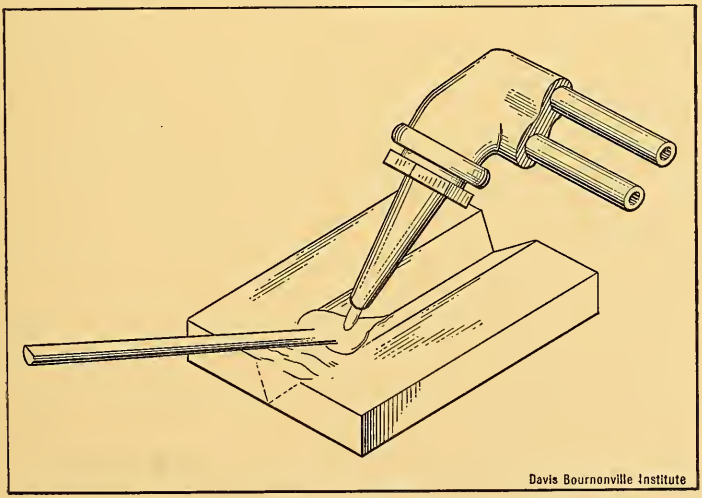

FIG. 6. CORRECT PRACTICE IN WELDING PREPARED JOINT. PUDDLE MELTING THE WELDING ROD

must be done outside or, as we say, in the field. Often it is necessary to make a weld on a heavy casting where it lies and where rigging must be erected to lift it and turn it over. Many field jobs are very difficult, and the job may be in a remote region where nothing is available except that which the welder takes with him. He must, therefore, learn to systematize his business and to prepare for the unexpected when he goes to do an outside job.

The welder should begin his career if possible in the shop where the tools and apparatus necessary for successful all-around welding are provided. When he has learned to know the conditions under which welding can be successfully accomplished in a shop, he will be able to create these conditions to a larger degree when sent out to do field work. The field work will require much more preparation than shop work and will often call for a higher range of skill and good judgment. Very often, if not usually, the field work is done under pressure. A mill or factory may be partly at a standstill because some apparatus has failed. The welder should learn to work quickly but without excitement no matter how great the emergency or how many are advising him that speed is imperative.

Machine steel, tool steel, steel castings, high-speed steel, cast iron and malleable iron have certain well defined characteristics which the oxy-acetylene welder should be able to recognize at a glance. It is important that he recognize these metals in order that he will not undertake to do impossible or unprofitable welding. Machine steel is steel low in carbon, and it can be welded with ease. Gray cast iron is easily welded but malleable iron is a difficult metal to weld because of the peculiar heat treatment it goes through in order to give it the malleable characteristics. Brazing is better than welding. Tool steel and high-speed steel can be welded but not by the usual methods.

Grading Steel with the Emery Wheel

A simple test for grades of steel is grinding them on an emery wheel. The steel high in carbon makes many white

hot sparks while a low carbon steel throws comparatively few. Mushet and high-speed steels when ground, produce dull red sparks. It is difficult to describe the characteristics of all metals as shown by the grinding test, and the best way for the welder to learn them is to take samples of known steels, wrought iron, cast iron, malleable iron, etc., and test them one after another. A little time spent in this way will be well repaid.

While it is possible to weld almost any metal with the oxy-acetylene torch, it is not commercially feasible to do certain classes of welding by this process. The welder should learn to distinguish between the classes of work that are commercially weldable and those which should be undertaken only to meet an emergency and which, under ordinary conditions, could be done more cheaply by other methods. It is better for him to reject a proffered job of welding than to undertake it when he knows that the result will be unsatisfactory to the customer because of the high cost. It is not good business to do work that will cause dissatisfaction either because of the quality of the work or its ultimate cost. Bargains are good bargains only when both parties are pleased and satisfied.

Cutting iron and steel with a torch is easily learned. The welder, however, should not despise the cutting game. He may find it very profitable to do cutting either in an emergency where the prompt removal of steel debris is necessary or in preparing for welding. Therefore, the welder should be able to use the cutting torch with skill and precision. The cutting torch can be used in preparing work for welding oftimes at costs far below any other. Suppose, for example, you are required to make a frame of angle iron. The torch will cut the angles to a 45-degree bevel quickly and at low cost. No other tools but the torch will be required except a bevel protractor to lay off the angle.

Learn to Estimate Costs

Knowledge of costs of the materials used, comprising oxygen and acetylene gases, adding material or welding rods,

fluxes, etc., is highly desirable. The oxy-acetylene welding

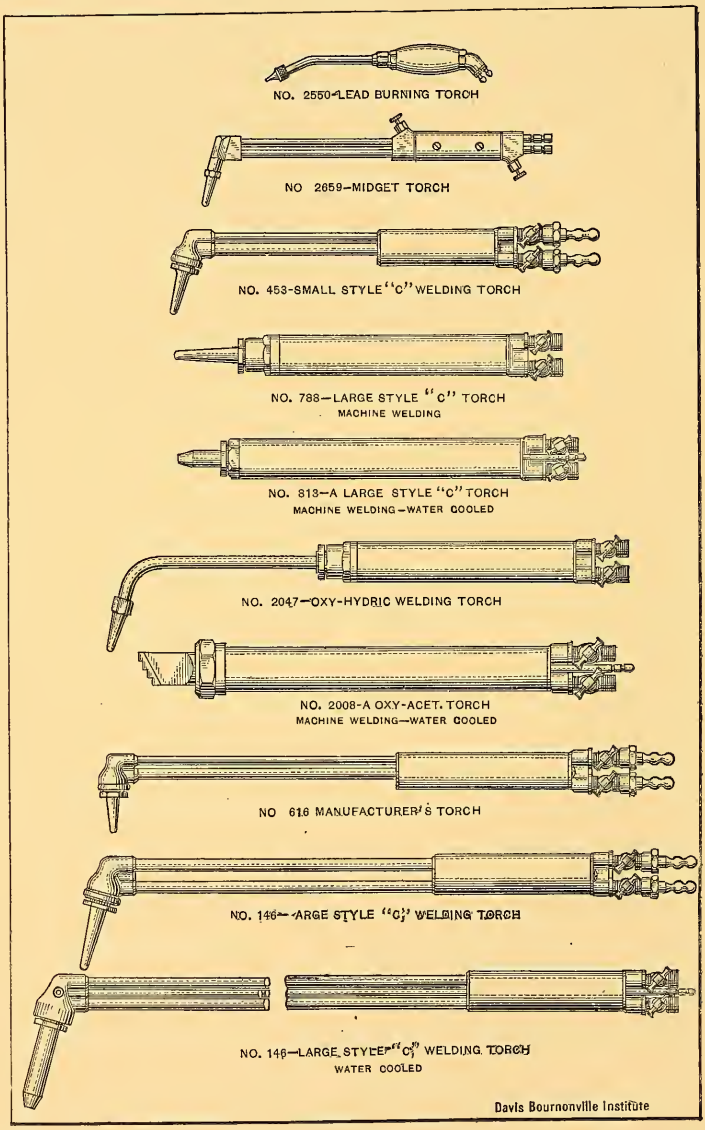
NO. 2550-LEAD BURNING TORCH
NO 2659-MIDGET TORCH
NO. 453-SMALL STYLE "C" WELDING TORCH
NO. 788—LARGE STYLE "C" TORCH
MACHINE WELDING
NO. 813—A LARGE STYLE "C" TORCH
MACHINE WELDING—WATER COOLED
NO. 2047—OXY-HYDRIC WELDING TORCH
NO. 2008-A OXY-ACET. TORCH
MACHINE WELDING—WATER COOLED
NO 616 MANUFACTURER'S TORCH
NO. 146—LARGE STYLE "C" WELDING TORCH
NO. 146—LARGE STYLE "C" WELDING TORCH
WATER COOLED
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FIG. 7. TYPES OF WELDING TORCHES AVAILABLE FOR ALL KINDS OF WELDING

business is one that offers large opportunities to the wide-awake progressive workman. He can start in business for himself with a comparatively small capital. If one goes into business for himself he should know the names of concerns from which he can obtain the best supplies and should compare the cost of acetylene in cylinders and of the gas made on his own premises with an acetylene generator.

Safety Considerations

Safety considerations and care of health are as important in the oxy-acetylene welding and cutting business as in any other line. The welder often is required to go into dangerous places to do emergency work. He should first of all provide suitable spectacles and goggles for protecting the eyes and should wear clothes suitable to his trade. Care of apparatus is imperative both for economy's sake and safety's sake. An acetylene cylinder filled with dissolved acetylene is commercially safe provided it receives ordinary care. But if it is mishandled and allowed to fall over or be struck by falling objects, the shell may be ruptured or the regulator broken off. It may be argued that this would mean only the escape of gas and no particular harm other than the loss of the gas and perhaps a shock to the nerves. But that is only part of the truth. Escaping acetylene in a closed room is exceedingly dangerous. Open lights will fire the gas and cause a disastrous fire. The flames may spread so quickly that men in the room will be unable to escape with their lives.

In the foregoing we have undertaken to give you some idea of the oxy-acetylene welding business and the requirements of the skillful welder. He has to be a pretty capable sort of a man who, first of all, is a good workman but who should have some commercial sense that would enable him to run a business of his own or to manage a department. He must be careful of his men and that means that he must be careful of his apparatus and in the methods he follows. He should also be careful of his reputation for keeping promises and being trustworthy.

Questions

1. How does one learn to use the torch?
2. What is autogenous welding?
3. What makes a successful weld?
4. What percentage of weld strength may be reasonably expected in mild steel?
5. What is the proper torch movement for thin steel?
6. What movement should be used on all prepared joints?
7. What is the difference in effect on the two torch movements on the parts to be welded?
8. How should the torch be held in relation to the joint?
9. What kind of a man would you pick to be a welder?
10. What is the best guarantee of a sound welded joint?
11. Can you tell different grades of steel by grinding them on an emery wheel?
12. What kind of sparks are thrown by high carbon tool steel?
13. How can you identify a malleable casting?
14. What would you do if required to mend a broken malleable casting?
15. Suppose that oxygen costs 2 cents a cubic foot and acetylene 1 cent a cubic foot? What would be the cost for gases when using the torch continuously with the No. 5 tip for one hour?

Acetylene and Oxygen Pressures

Davis-Bournonville Style C Welding Torches
with Style 99 and 100 Tips

Tip No.	Thickness of Metal Inches	Acetylene Pressure Lbs.	Oxygen Pressure Lbs.	Acetylene* Consumption Per Hour	Oxygen* Consumption Per Hour
00	Very Light	1	1	0.6 cu. ft.	0.8 cu. ft.
0		1	2	1.0 "	1.3 "
1	1/32–1/16	1	2	3.2 "	3.7 "
2	1/16–3/32	2	4	4.8 "	5.5 "
3	3/32–1/8	3	6	8.1 "	9.3 "
4	1/8–3/16	4	8	12.5 "	14.3 "
5	1/4–5/16	5	10	17.8 "	21.3 "
6	5/16–3/8	6	12	25.0 "	28.5 "
7	7/16–1/2	6	14	33.2 "	37.9 "
8	1/2–5/8	6	16	42.0 "	47.9 "
9	5/8–3/4	6	18	58.0 "	65.9 "
10	3/4–up	6	20	82.5 "	94.0 "
11	Extra Heavy	8	22	89.0 "	101.2 "
12		8	24	114.5 "	130.5 "

Operators frequently adjust the pressure regulators from one to two pounds above the figures given in the table to allow for gauge variations and drop of pressure when the gases are supplied in cylinders.

* Gas consumption per hour is the maximum with torch burning continuously.

DAVIS-BOURNONVILLE
OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

EXPANSION AND CONTRACTION—PREHEATING

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

Form 385

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EXPANSION AND CONTRACTION—PREHEATING

Changes of Temperature Change Length, Breadth and Thickness—Expansion Must be Provided for in Welding—Cost of Heat Produced by Torch too High for Preheating Use—Preheating Necessary for Large Castings—Setting Up a Casting for Preheating and Welding—Preheating a Broken Pulley. Preheating a Bronze Valve Seat Casting—General Theory of Preheating.

Heat is a mode of motion. According to scientific theory the molecules of all matter are in a state of vibration or movement to and fro. The extent of vibration depends on the temperature, increasing as the temperature rises, and decreasing as it falls. According to this accepted theory there is no movement or heat vibration at absolute zero. The absolute zero or point of no temperature is 273 degrees below the freezing point of water on the Centigrade scale and 459 degrees below the zero point on the Fahrenheit scale.

Matter exists in three forms—solid, liquid and gaseous. At very low temperatures all gases and liquids become solid. On the other hand, all solids melt at some temperature; and at very high temperatures they become gases. We find water in the three forms in nature. It freezes at 32 degrees and becomes ice, and boils away in steam or gas at 212 degrees F.

Changes of Temperature Change Length, Breadth and Thickness

Changes in temperature mean changes of length, breadth and thickness. A bar of iron or steel expands as it is heated and contracts as it cools. The expansion of a bar of steel by heat is attended with great force. It is practically impossible to prevent a bar expanding with heat, and contraction cannot be prevented as it cools. In fact, so great is the contraction force that if a long rod is heated and fixed firmly in a cast iron frame so that it cannot contract as it cools, it will rupture or pull itself apart, and then each part will

contract. The same holds true of a casting. If a casting is made in the foundry without due regard to the contraction stresses, it may come out of the mold broken. Some parts will have contracted more than others, and not being able to contract freely, naturally they have pulled apart. Every molder and pattern-maker knows how necessary it is to provide for contraction stresses in making castings. The success of the heavy iron founder largely depends on adapting his work to the peculiarities of cast iron in this respect.

Expansion is Proportional to the Rise in Temperature

The expansion in length, breadth and thickness is proportional to the rise in temperature, and contraction is also proportional to the fall in temperature in the same ratio. The expansion rates of metals differ, being greater for copper and aluminum, for example, than for cast iron. The expansion of copper is about one-tenth of an inch per 1000 degrees F. per foot. This means that a copper bar one foot long expands one-tenth of an inch when raised 1000 degrees in temperature. A gray iron casting when preheated to 1500 degrees expands a little over one-tenth of an inch per foot, the expansion rate being 0.068 inch per foot 1000 degrees rise in temperature. Aluminum expansion is over twice that of cast iron; the expansion per foot per 1000 degrees is 0.148 inch.

Great care must be taken when preheating aluminum castings that the safe temperature is not exceeded. It is not safe to preheat aluminum over 600 to 800 degrees, and when heated the aluminum casting must be handled with great care as it becomes weak and brittle.

Expansion Must be Provided for in Welding

When we undertake to weld two pieces of metal together, we must provide for expansion, or we shall not be successful. The flame of the torch raises the temperature enormously at the place where the weld is being made, and the heat spreads throughout the pieces. The welding is progressive and as the metal is welded at a given point, the torch moves on and the metal begins to cool off and contract.

The force of contraction may be so great that the joint will pull apart in places after it is welded.

When preparing to weld two bars of steel together, we must lay them so that expansion and contraction will be provided for. The rule is to provide 2½ per cent of the length of the weld for expansion and contraction. If the joint is 10 inches long we should lay the pieces so that the far end of the weld will be ¼ inch further apart than the end at which welding is begun. If this rule is followed you will have little, or no trouble on a simple job.

The action is this: The two pieces are laid with a space between them, which tapers so that it is ¼ inch greater at the far end. We tack them together and begin to weld. As welding proceeds, the molten metal cools and contracts. The contraction causes the parts welded to act like a hinge, drawing the unwelded ends closer and closer together as the welding proceeds. Finally, when the torch has reached the far end you will find that the ends have been pulled together to just about the right space for finishing the weld. If insufficient space is left contraction cannot take place in the cooling parts and destructive stresses may be set up.

It is often an extremely difficult matter to provide for expansion and contraction when welding castings. In fact, the skill of the welder is displayed by the way in which he prepares the job and provides for expansion and contraction stresses.

Effect of Torch Flame Comparable to Wedge

The effect of the torch flame on a casting may be compared to that of a wedge or tapered drift if driven into the crack or between the parts to be welded together. Suppose that a casting has a crack running from one edge toward the center. The place to start welding is the inner end of the crack. If the crack is short no preheating may be necessary because the stresses produced will be comparatively slight. But if the crack is long the local expansive effect of the torch flame may be disastrous unless it is reduced by preheating. You can see what the probable effect would be on a thin

casting, say two feet square and having a crack in one side running toward the center a distance of six inches, if you drove a thin wedge into the crack. The effect would invariably be to extend the crack and make the conditions worse.

Suppose that the same casting has a blowhole near the center which you wish to weld up. If you start to weld in the hole you heat the metal to a high temperature around the hole and produce expansion stresses of great force. The condition is practically the same as though you drove a tapered drift into the blowhole with a heavy sledge. The drift forces the metal apart to such an extent that the elastic limit of the iron is exceeded and a rupture results. So it may be when welding cast iron without preheating.

"All that goes up must come down," and all that is expanded by heat above normal, must sometime contract to normal dimensions when the temperature returns to normal. Often the inexperienced welder has the unhappy experience of making a good weld in a casting and then seeing the metal crack elsewhere as it cools. He mends in one place and breaks it another. This is clearly due to contraction stresses resulting from not preheating or preheating at the wrong place. Preheating may be done so badly that it makes conditions worse instead of better.

In the talk on heat and temperature we endeavored to make clear the difference between the heat of a body and the temperature of a body. Heat is expressed in quantity and temperature in degrees of intensity. The oxy-acetylene torch produces a flame of great intensity but of not much volume. It is true that we can change the amount of gas consumed, the size of flame and the amount of heat by changing the tips. But even with a large tip, the total amount of heat produced is not great compared with that which can be produced in a comparatively small furnace.

Cost of Heat Produced by Torch too High for Preheating Use

The cost of the heat produced by the oxy-acetylene torch

is much higher than the cost of heat generated in a forge or with an oil blowtorch. You should get this very clearly in mind, as it has an important bearing on oxy-acetylene welding in general. The oxy-acetylene torch produces a flame of high temperature, but it yields comparatively little heat. The heat produced is more costly than the heat of a coal fire, charcoal furnace or an oil blast.

In what has just been said about expansion and contraction you learned something about the forces produced by heating and cooling and the necessity of providing for their free play. You cannot prevent a piece of metal expanding when it is heated, nor can you keep it from contracting as it cools. If you attempt to prevent expansion or contraction you are likely to cause a fracture in the welded joint or some other place.

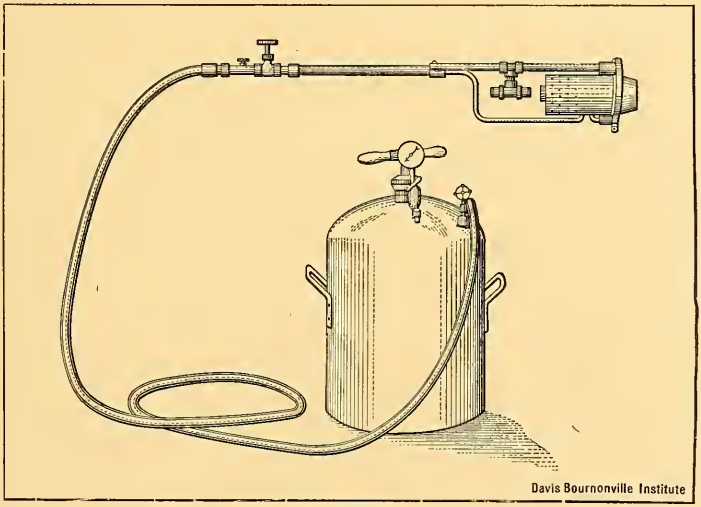

FIG. 1. HAUCK KEROSENE BLOWTORCH FOR PREHEATING CASTINGS AND FORGING FOR WELDING

Preheating Necessary for Castings

When welding a large casting or any casting of other than simple form, or even castings of simple form under most conditions preheating will be necessary. By preheating

we mean heating the part to be welded with some other source of heat than the oxy-acetylene torch. The blacksmith's forge fire may be used when the parts are comparatively small but in general it is better to use some source of heat that can be readily applied to the parts when lined up on the welding table or to provide a special preheating fire or furnace on which the parts can be lined up and welded without moving after having been heated to the required temperature to relieve the expansion and contraction stresses.

The choice of source of heat depends on local conditions and character of the work. An oil blowtorch or several oil

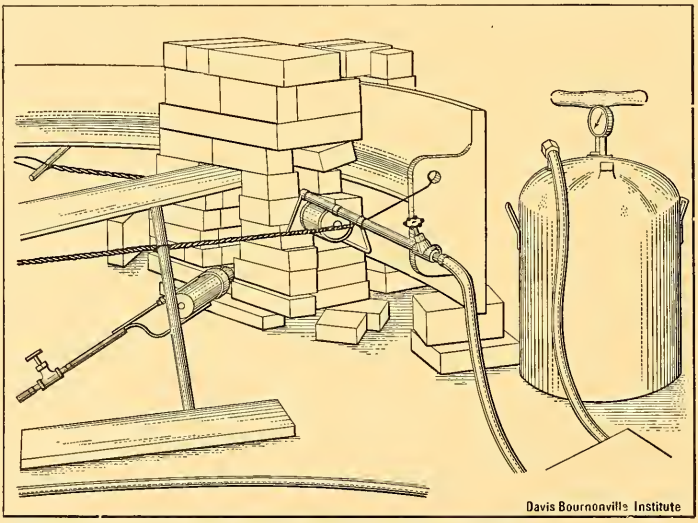

FIG. 2. PREHEATING A BROKEN PULLEY SECTION WITH A FIRE-BRICK OVEN AND KEROSENE BLOWTORCHES

blowtorches may generally be used with satisfaction if the castings are not too large. These torches are made in a variety of styles and capacities. They are simple, compact and produce a large soft flame of great heating power. One or more of these torches will soon heat castings to the degree where the broken parts may be welded without fear of setting up destructive expansion and contraction stresses. In localities where hardwood charcoal can be ob-

tained it is used in preference to oil blowtorches by some welders, however, as they believe better results can be obtained especially with large castings into which the heat has to be soaked for a long time before the internal stresses can be equalized. Another advantage of a hardwood charcoal preheating fire is that heat can be applied to the casting while welding is going on without creating highly uncomfortable conditions for the welder. The blowtorch flame, is likely to make things very uncomfortable for the welder if kept going after the welding starts.

A preheating stove is a useful if not indespensable accessory of the welding shop. It is satisfactory for preheating comparatively light castings which may be laid on the top and heated by conduction and convection. The stove is operated with oil or gas and the flames do not come directly in contact with the casting to be preheated. The preheating stove is not intended to be used as a welding table but merely for preheating parts which can be quickly welded after being removed to the welding table.

Setting Up a Casting for Preheating and Welding

When preparing a casting for preheating and welding it should be laid on the welding table, the preheating forge or a brick floor and blocked up with firebricks so that the flames from the blowtorch or charcoal may pass beneath. It is essential that the floor or table be fireproof, of course. In order that the blowtorch may be used economically it is desirable that the casting be so protected that the heat is not radiated rapidly. Asbestos paper is a convenient and effective material for the purpose. It is furnished by the manufacturers in large sheets and is light, clean and easily applied. All parts of the casting should be covered except that part where the welding is to be done, and when the joint is welded it should be covered also and the whole casting allowed to cool down uniformly.

If asbestos paper is not available, dry ashes or dry sand may be used to cover the casting and conserve the heat but such substances are not satisfactory for the purpose. It is

difficult to apply dry ashes so as to cover all parts of a casting without using an excessive quantity. They are in the way when welding and are likely to fall into the joint and give trouble. When the job is finished there is a mess to clean up. By all means use asbestos paper if you can get it. The cost will be repaid many times in satisfaction, cleanliness and general efficiency.

Preheating a Broken Pulley

In the foregoing we have dealt with general preheating but often it occurs that preheating all over is unnecessary and even undesirable. If you have to weld a broken pulley you have a problem that requires some study. If a spoke is broken it could not be welded without providing for expansion and it is a difficult, expensive, and troublesome job to preheat a large pulley all over and, in this case, undesirable. What we should do in a case like this is to preheat the pulley rim and spokes each side of the broken spoke. The rim is expanded by preheating and the broken spoke pulled apart at the break. Now the oxy-acetylene flame can be applied and the break welded without fear of disastrous consequences.

When the weld is finished it should be covered with asbestos paper and the heated parts of the rim may be exposed to the air. The problem is to make the rim and spoke cool down at such respective rates that there will be no severe contraction stress produced. A job like this requires some experience as a job welder but the theory is one that you can readily understand and apply as you are gaining experience.

If the pulley is broken in the rim, the hub should be preheated and a jack should be applied between the spokes so as to spring the broken rim apart. When the rim is sprung apart space is made available for welding and the consequent expansion. Here again experience is required in order to judge just how much the hub should be preheated and the rim sprung apart so that when welded and cooled it will be round and true.

Preheating a Bronze Valve Seat

A bronze casting for an air pump valve chamber which forms a seat for several flap valves must be preheated for welding with due regard to the thin metal spiders that support the guide for the valve stem in the center. If a casting of this type is preheated with a charcoal fire without proper protection for the thin metal sections the gases and flames will naturally pass through the openings and the thin metal parts will heat quickly to a high temperature long before the body of the casting has become hot. This is improper preheating. If a crack between adjacent valve seats is welded after preheating in this manner the probability is that the casting will pull apart in another place as it cools. The contraction stresses set up are so severe that it would be a miracle if fresh cracks do not develop. A casting of this type must be handled intelligently. More skill is required for preheating than the actual welding. The flame of the preheating fire must be prevented from passing through the openings and overheating the thin metal sections. This may be accomplished by laying a thin metal plate over the fire and placing the casting on the plate. The flames then must pass around the plate and heat the casting indirectly. It will take longer to preheat in this manner but the results will undoubtedly be much more satisfactorily in the long run.

When a casting of this kind has a crack between two adjacent valve seats the aim in preheating should be to expand the rim so as to separate the margins of the crack slightly. Then when welded the metal in the joint which has been raised to the fusing temperature will be able to contract without exerting a tremendous stress in the adjacent part. The rim will follow the contraction stress because it has itself been expanded beyond the normal size.

General Theory of Preheating

The general theory of preheating may be expressed in a few words. Parts to be welded are preheated in order to overcome expansion and contraction stresses. It is cheaper

to heat a large metal casting with a charcoal, coal or oil fire than with the oxy-acetylene flame. Preheating must be done with reference to the individual job and no set rule can be laid down for preheating castings of irregular shapes. They should, in all cases, however, be preheated for the purpose of providing room for the local expansion produced by the oxy-acetylene flame and the amount of preheating should be calculated so that the parts will come back to approximately their original position when cool. When large castings are preheated the radiating heat will be considerable no matter how well they are protected. The welder should be suitably dressed for the job, and shields should be provided to fend off the radiated heat whenever possible.

Effect of Preheating on Torch

On very large and heavy work the use of special water-cooled torches will be necessary as the torch of the ordinary type may become so hot as to be unmanageable because of flashbacks. However, the skilful use of asbestos paper on a preheated casting will largely overcome the trouble many times. Another resort is a pail of water into which the torch is dipped from time to time to cool off the head.

Questions

1. In how many forms does matter exist?
2. What is the effect of changes in temperature on dimensions of a casting?
3. Why is it necessary to provide for changes of dimension due to changes in temperature?
4. Why not use the torch for preheating castings?
5. What is the advantage of the oil blowtorch for preheating?
6. Why is hard wood charcoal preferred by some welders?
7. What should be done to conserve the heat when preheating?
8. What precaution should be taken with a welded casting when cooling down?

9. How would you proceed to preheat a pulley with a broken rim?
10. What would you do if a spoke only was broken?
11. Having welded a broken pulley rim, how would you protect it while cooling down?
12. How should the parts of a pulley be protected when the spoke only has been welded?
13. What effect may preheating have on the torch?
14. What should be done to stop the trouble?

Notes

Notes

DAVIS-BOURNONVILLE
OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

PREPARING THE JOINT FOR WELDING

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JERSEY CITY, N. J.

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PREPARING THE JOINT FOR WELDING

Reason Why Beveling is Necessary—Angle of Bevel—Thick Casting Should be Beveled on Both Sides when Possible—No Beveling Required on Thin Aluminum Castings—Methods of Cutting Bevels—Care Must be Taken to Remove All the Slag and Oxide from the Joint Before Starting to Weld—Parts Should be Cleaned—Alignment and Allowance for Contraction.

One of the first principles of sound welding, as has been repeatedly stated in these lectures, is securing complete fusion and perfect union of the welding material and the edges of the plates to be welded. When the material is thin—say $\frac{1}{16}$ to $\frac{1}{8}$ of an inch—you can weld successfully when the edges are square or as left by the cutting shear. The heat of the oxy-acetylene flame will penetrate deep enough to produce complete fusion and satisfactory union. But when thicker plates are to be welded it is necessary to bevel the edges in order to obtain the best results. By beveling we mean cutting away the corners so that when the two plates are brought close together they form a trough or vee.

Reason Why Beveling is Necessary

The reason for beveling the plates to be welded is easy to understand. It is necessary because the heat of the flame suitable for welding will not penetrate and produce perfect fusion beyond a depth of say $\frac{1}{8}$ to $\frac{3}{16}$ inch. The depth of penetration, of course, depends on the size and shape of the flame; the neutral flames that can be obtained with the smaller sizes of tips will not give much greater penetration than the depth stated. Hence, when the parts to be welded are thicker than $\frac{1}{8}$ of an inch, we should cut away the metal at the sides in order that the flame may be free to operate on the center of the joint and fuse it perfectly clear through. We then fill in the vee by using adding material until it is level full.

Angle of Bevel

It has been found by experience that the sides of steel and cast iron plates should be beveled at an angle of about

45 degrees. When two plates which are beveled at an angle of 45 degrees are butted together the included angle is double or 90 degrees. A lesser angle may be used on brass and bronze, and is generally advisable but the welder should not experiment with any but the recommended bevels until he has become skilled in the use of the torch and able to recognize instictively when he is getting perfect fusion and union. Then he can try welding plates with lesser angles of bevels until he finds just what the limits are. It is, of course, advantageous to use a lesser angle wherever possible as the amount of adding material and gas required are reduced.

Thick Castings Should Be Beveled on Both Sides When Possible

If the part is very thick and it can be approached and welded on both sides, it is better to bevel and weld on both sides. The cross section area of the two vees when made of the standard angle is only one-half the cross section area of the single vee of the standard angle made all from one side. This you can readily prove for yourself by laying out a vee say for a two-inch plate, and then laying out two vees opposite in the same thickness of plate.

The double vee reduces the amount of adding material and the quantity of gases required to weld. Moreover, you will obtain a better weld and less labor will be required for beveling the joint also. In many cases, however, it will be impossible to work on both sides of the piece. In that case, of course, the beveling must be done on one side only. Should the piece be very thick it is then advisable to reduce the included angle considerably; if the angle is reduced to say 60 degres for a thick weld, the skilled workman should be able to produce good work because he can so manipulate the torch that the actual welding will take place in an angle of approximately 90 degrees while the untouched sides of the trough will be at a lesser angle. In other words, if the sides of the vee are inclined at 60 degrees the skilled workman will start to work at the bottom and fill in so that the sides of the zone of welding are at a 90-degree angle and he will

maintain this relation throughout until the job is finished. It

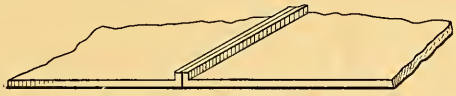

FIG. 1 FOR 20 GAUGE AND THINNER

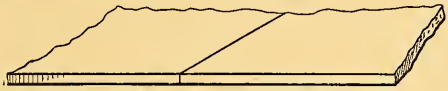

FIG. 2 FOR 14 GAUGE TO 18 GAUGE

FIG. 3 FOR 8 GAUGE TO 14 GAUGE

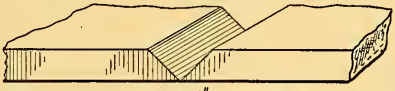

FIG. 4 FOR $\frac{5}{32}$" METAL AND UP

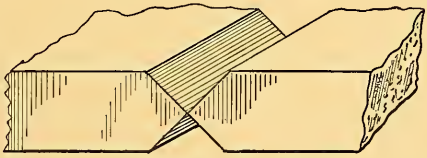

FIG. 5 FOR HEAVY SECTIONS

FIG. 8 COMPARISON OF PREPARATION

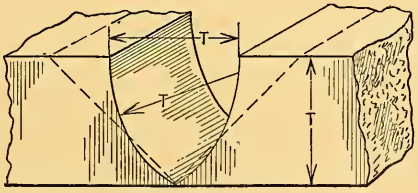

FIG. 7 FOR VERY HEAVY SECTIONS

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SHOWING METHODS OF PREPARING THIN AND THICK METAL FOR WELDING

would not pay, of course, to resort to this expedient on thin sections but on thick sections it will save much time, labor, adding material and gas.

No Beveling Required on Thin Aluminum Castings

Cast iron and steel, as already stated, should be beveled at an angle of 45 degrees on each edge, making the included angle about 90 degrees. Aluminum need not be beveled so much as the lesser angle will work satisfactorily in most cases. In fact, when welding aluminum ¼ inch thick or less no beveling at all is necessary where the welding iron or spud is employed to break up the oxide. Experience is required, however, to work successfully in this manner as the operator must produce the weld without actually seeing it. He manipulates the molten metal with the welding tool working out the oxide with a puddling hook so that the pure metal can flow together and produce intimate union.

Methods of Cutting Bevels

Various methods may be employed for cutting the bevel depending on the tool available. The quickest and easiest method generally to follow in the work shop is to grind the edges with an emery wheel using an ordinary floor grinder for the purpose when the parts are not too heavy. In the case of heavier castings which cannot be taken to the wheel, it is good practice to use a portable grinder driven by a flexible shaft or an electric motor. In some welding shops swinging frame grinders are provided for beveling joints but they take up considerable room and are not as convenient to use as the flexible shaft arrangement.

In the absence of means for grinding a bevel the workman must cut away the metal with a hammer and chisel or with a file. Filing is a very slow and expensive process and the welder should learn to use the hammer and chisel effectively. Chipping with a hammer and chisel requires considerable training but like most other operations, requiring manual skill, it is largely a matter of practice provided one starts out with the right kind of tools and follows approved

methods. The choosing of hammer is important. Use a ball pene machinist's hammer weighing about 1½ pounds. The handle should be smooth and flexible. The length of the hammer over all should be about 16 inches. This is the hammer that will be used for most ordinary use but heavier and lighter hammers should be used for heavy and light work. A supply of sharp chisels should be provided. It is useless to try to chip a bevel on cast iron or steel without a sharp chisel. You cannot do it effectively any more than a carpenter can plane a board smooth with a dull plane.

Hold the chisel easily in the left hand and grasp the hammer handle at the end and swing the hammer freely over the shoulder. Do not look at the end of the chisel but look at the point where you are cutting the chip. Of course, you will hit your hands some nasty raps when learning but you will make more rapid progress if you start right and stick to right principles. The workman who tries to chip holding the chisel in a death grip and hammer handle in the middle while he looks at the end of the chisel, is making hard work of an easy job. He works in anything but a workmanlike manner.

The hammer and chisel when properly used are very effective tools, and we hardly over estimate the importance of learning to use them effectively. When chipping steel the chisel point will move more smoothly if it is dipped occasionally in oil. A small bunch of cotton waste saturated with oil may be laid alongside the work to lubricate the chisel edge.

The hacksaw may be advantageously used for beveling castings, especially when light and easily broken. Successive cuts should be made with the saw along the margins, at an angle of 45 degrees. These cuts should be not more than ⅜ inch apart in ½ inch metal. When the saw cuts are finished the metal is cut away with the hammer and chisel. The saw cuts make chipping much quicker and easier, and reduce the chances of breakage.

If a drilling machine is available, a series of circular vees can be drilled along the crack with a flat drill ground on the point to an angle of 90 degrees. The vees should be drilled until the point of the drill nearly penetrates the cast-

ing. The hammer and chisel can then be used to cut away the partitions between the drilled vees very quickly. The vees should be drilled as close together or should even over-lap in order to leave as little metal as possible to be cut away with the chisel.

If preparing steel parts for welding and much beveling is necessary it can be done much more quickly with a cutting torch, however. The torch will remove ten cubic inches while one is being cut away by an emery grinder or a hammer and chisel. The welder should take advantage of all possibilities of his trade to save time and labor. Care must be taken to remove all the slag and oxide from the joint before starting to weld.

When beveling the joint it is advisable in many cases to leave narrow parts unbeveled to assist in lining up when ready for welding. These narrow unbeveled parts are "witness points" by which the original relation of the pieces can be ascertained and maintained. The location of these unbeveled parts will depend on the nature of the piece and its size. It should, in general, be as narrow as possible in order not to make broad defective spaces in the weld. It may be advisable in some cases to chisel them away after the casting has been tacked together and partially welded.

Parts Should Be Clean

When preparing parts for welding that are covered with oil or grease, it is generally advisable to clean them thoroughly, using gasoline or kerosene to cut the grime loose. This may seem like unnecessary labor but it is not so. The workman cannot do the job justice if he is smeared with dirty oil and is in a generally uncomfortable condition. A little time spent in making the work clean and placing it in a position where he can work comfortably will be well spent. Cleaning the work will not only permit better welding to be done but it will save accumulating an unnecessary amount of grime and making the welder present a disreputable appearance. A skilled workman should be able to work without getting grease and dirt all over him unless it be on some emergency job where he is surrounded by unclean parts.

Alignment and Allowance for Contraction

Preparing the joint for welding includes alignment. When working in the workshop the alignment will be simplified by the use of a welding table. But when welding in the field the workman may have to resort to various expedients in order to obtain a satisfactory job. The use of straightedges, levels, plumb bobs and the eye may be necessary. Look the broken casting over and see how the parts should be when welded. Block them up so that when tested with a straightedge they are in line or if the straightedge cannot be used, measure from a level floor. Unless means are available for aligning the broken parts carefully, it may be very unsafe to go ahead and weld as the result is likely to be unsatisfactory. It may be necessary in some cases to place the broken parts in their original position and mark them in such a manner that they can be aligned on the welding floor to agree with the position when assembled.

Remember that allowance must be made for the effect of contraction when welding without preheating. A steel test bar should be adjusted out of line slightly so that it will be approximately straight when welded. The contraction on the side of the vee will be somewhat more than for the opposite side unless preheated.

Questions

1. How deep will the fusing heat of the smaller torch flames penetrate into metals when welding?
2. Why is beveling necessary?
3. What is the greatest thickness of steel than can be welded without beveling?
4. What is a prepared joint?
5. What is the recommended angle of bevel?
6. What should be the included angle when two beveled edges of steel plates are butted together?
7. Why should thick castings be beveled on both sides?
8. What is the reason why gas and adding material are saved by beveling on both sides?

9. Is it necessary to bevel an aluminum casting ¼ inch thick?
10. How would you proceed to cut the bevels on a light casting?
11. Of what use is the hacksaw in beveling?
12. When can the cutting torch be used for beveling?
13. What precaution should be taken in regard to slag and oxide on a joint beveled with the torch?
14. What is the first thing to be done when preparing to weld a greasy casting?
15. What is the straightedge used for when setting up for welding?

Notes

DAVIS-BOURNONVILLE
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COURSE OF INSTRUCTION

Lecture

WELDING RODS AND FLUXES

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WELDING RODS AND FLUXES

How a Tinsmith Solders a Joint—Soldering Differs from Welding—Welding Rod or Adding Material Should be Low in Carbon—A Welded Joint is a Fused or Cast Joint—Care Should be Taken of Adding Material—Never Use Commercial Wire for Welding Rod—Reason Why Malleable Iron Should Not be Welded—Function of Fluxes—Flux Should be Chosen for Kind of Welding.

When a tinsmith solders a seam in a tin can he melts the solder with the soldering bit and applies the bit to the tin which quickly rises to the amalgamating temperature and unites with the solder. The solder flows into the joint if the metal is made chemically clean by the use of tinner's acid or other flux. Nothing is fused but the solder and this is melted with the soldering bit.

Soldering Differs from Welding

But in oxy-acetylene welding the conditions are quite different. Welding rod or adding material is used to fill the joint the same as when soldering but it must not be melted by the direct flame of the torch. To do otherwise is to invite trouble. The welder must produce a puddle of molten metal in the parts to be welded which is sufficiently hot to melt the adding material. Then only can he be sure of perfect fusion and intimate union. The heat must be transferred from the torch flame through the puddle to the welding rod. The adding material then forms a dependable link between the sides of the joint, provided it is of the right material. The choice of adding material is very important. It must fuse without oxidizing easily and must have strength when cold in proportion to the strength of the parts welded. Success or failure may depend on whether or not the proper adding materials are used on the joint. Many failures of oxy-acetylene welding have been due to the use of fence wire or other commercial wire, in ignorance of the danger thus invited.

Welding Rod or Adding Material Should be Low in Carbon

Mild steel should be welded with a welding wire that is low in carbon content. The nearer the welding rod approaches in composition to pure Swedish iron the better will be the welded joint in general. Swedish iron melts under the neutral flame with very little tendency to oxidize, and combines with the molten steel smoothly, forming a union free from blowholes and hard spots. Some welders take pride in the fact that they are not limited to the use of the recommended welding rods and boast that they can use almost any ordinary wire picked up from the scrap heap. It is true that some commercial low carbon steel wire can be used for oxy-acetylene welding but it is not true that this nondescript wire will produce uniformly good welds. The welders who use it deceive themselves and their customers. Sound welds cannot be made with commercial wire in general. Of course, it is true that many welding jobs require no great strength and a welded joint may be made strong enough with inferior materials to withstand all the stresses and shocks that it will ever be subjected to in use. The practice is so bad, however, that welders should not be backward in discouraging it wherever met.

Why is the use of commercial steel wire bad practice? To answer the question we must go somewhat into the theory of welding and the influence of carbon on melting points.

Why Swedish Iron or Special Low Carbon Steel is the Best Adding Material

The reason why pure Swedish iron and special low carbon steel wire are better welding materials than ordinary commercial wire is first, the comparatively high melting point. The lower the carbon content of iron the higher its melting point. Pure iron melts at about 2,780 degree F. while the ordinary grades of mild carbon steel melt at from 2,500 to 2,600 degrees F. The temperature of the molten puddle of steel then must be raised nearly 200 degrees above the fusing point of the parent metal before the welding rod will be raised to the temperature

sufficient to cause it to fuse and add metal to the puddle. There can be little doubt when welding under this condition that the parent metal, puddle and adding material are perfectly blended when the joint cools off. Now you begin to see how important it is that the recommended practice of making the puddle melt

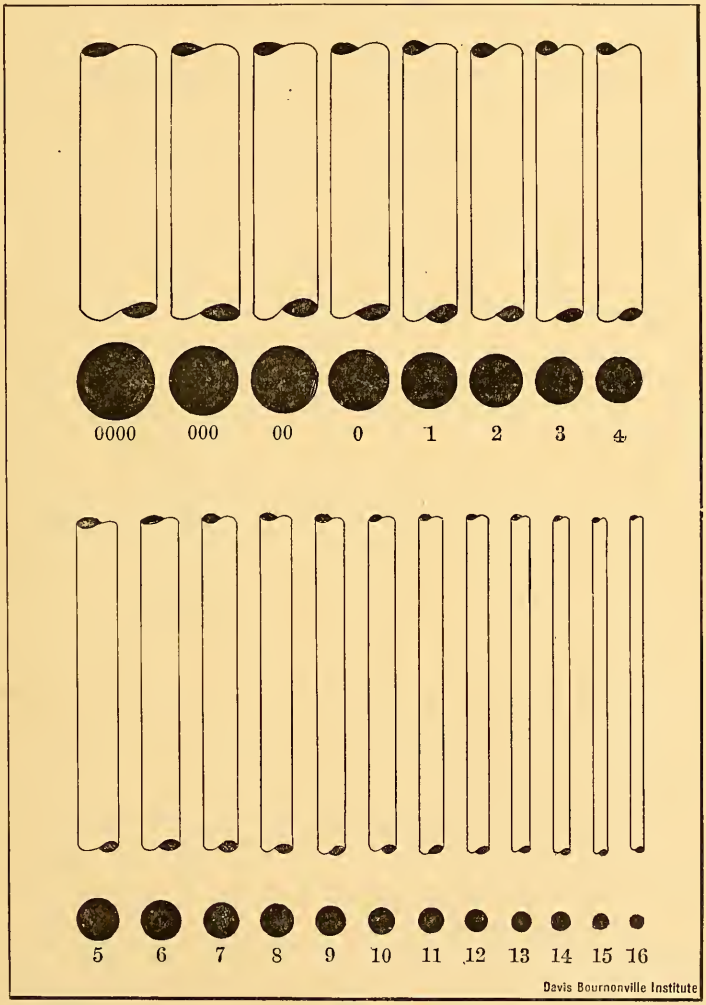

FIG. 1. COMMERCIAL STEEL WELDING RODS AND GAUGE SIZES

the welding rod is when you compare the fusion temperature of various grades of steel and iron.

What Happens when Commercial Steel Wire is Used for Adding Material

Suppose the welder picks up from the scrap heap a coil of steel wire, having for example, a carbon content of from 0.25 to 0.30. The carbon content may not be so high but he has no means of knowing what it is. Steel containing 0.30 carbon will melt at about 2,500 degrees F. or at a slightly lower temperature than mild steel plate of 0.10 carbon. Suppose the welder follows the recommended practice. He forms a puddle with the torch flame and applies his scrap adding material to the puddle. It melts readily and supplies the puddle. He welds the joint and regards the finished job with satisfaction! Suppose now the joint is put to a tensile test, and is pulled apart in a testing machine. What will be the probable result? The probable result is that that welded joint which looks so nice and smooth will pull apart under a stress of only 50 to 60 per cent of the strength of the unwelded steel plate. An examination of the joint will show that there is a general lack of penetration. The welding material *adheres* to the parent metal in spots. There is no general *cohesion.* It is more of a cemented joint than a welded joint. Why is this condition found? Because sufficient temperature was not produced in the puddle to insure breaking down the sides of the parent metal and complete union. The adding material melted at too low a temperature to form a sound weld. It is only by using the welding rods supplied by reputable manufacturers that you can be sure of the carbon content and the approximate fusing temperature of the metal. Do not get into the habit of using inferior materials as you will have reason to regret it some day when one of your jobs fails and seriously damages your reputation as a welder.

A Welded Joint is a Fused or Cast Joint

An oxy-acetylene welded joint is one united by fused or cast materials. You know that all cast materials are inferior in strength to rolled or hammered metals. But some cast ma-

terials are better than others. You have seen cast iron so brittle and frail that it would break apart from a light blow with a hammer. On the other hand, you have seen some castings so strong that a comparatively light section could be broken only by a heavy blow with a sledge. So it is with an oxy-acetylene welded joint. If you use an inferior adding material you will make a cast joint of inferior strength. It may be so brittle that a light shock will break the joint apart and make your hours of labor useless. It is better to expend a few cents for adding material of known reputation than to run the risk of making

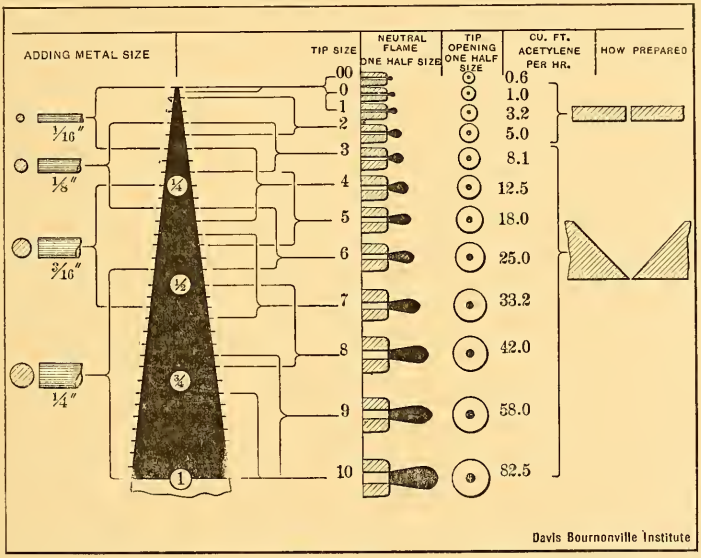

FIG. 2. SIZES OF WELDING RODS, TORCH FLAMES, TIPS, THICKNESS OF METAL AND PREPARATION

poor welds and saving a little money—when you risk so much by so doing.

It is especially important when welding cast iron to use cast iron welding rods high in silicon. The analysis of a welding rod, however, does not necessarily determine its value for welding. Much depends on the method of manufacture. Cast iron welding rods must not only be made from a fine grade of cast iron high in silicon and low in manganese and sulphur,

but they should be made according to a certain approved method. Cast iron structure is affected by the rate of cooling. The best cast iron welding rods are cast in metal molds which insure density of metal and freedom from blowholes and sand.

Care Should Be Taken of Welding Rods

You may not have realized this important fact that your welding rods should be clean. Never use a rusty rod or one covered with sand or dirt. A rod cast in sand is likely to have some sand adhering to its surface. The sand may melt with the iron and change the chemical make-up of the metal in the joint. The same holds true if your welding rods are rusty. Rust is oxide-of-iron. The oxygen in the rust may remain in the molten metal and tend to make a weak oxidized joint. You know how careful you must be to adjust your gas to produce a neutral flame, you do this to avoid oxidizing the metal and take good care that you get the correct mixture. Then why be careless in the selection of your welding rods and thus defeat your care in adjusting the flame? If you are careless in the selection and care of rod you make practically useless all the care taken in flame adjustment and torch manipulation.

Manufactured Welding Supplies

The welding materials furnished by reputable concerns are carefully manufactured. They are put up in packages that protect them from rust, and are cut in lengths convenient for use so that waste may be reduced to a minimum. This brings up a point in welding practice that should be observed carefully. The welder need waste no adding material as he can readily weld a short piece onto a longer one and thus use it up completely. He also should learn to bend steel and bronze welding rods to a convenient angle for use as a bent rod, which can be applied with greater facility than a straight rod. Of course, cast iron rods cannot be readily bent, and it is not common practice to use any other than straight lengths of cast iron stick. There may be conditions, however, that make the use of other than straight lengths desirable or necessary. Short sections of cast iron adding material can, of course, be welded to a long rod at an angle and used in this shape the same as steel or bronze.

How Welding Rods are Supplied

Welding rods are commonly supplied for wrought iron and steel in various diameters ranging from $\frac{1}{16}$ inch to $\frac{3}{8}$ inch, inclusive and in lengths of 36 inches. A 36-inch length makes two 18-inch lengths which are more convenient for use on many jobs. The accompanying illustration, Fig. 1 shows other sizes of welding wire by U. S. wire gauge number and the actual size. Fig. 2. shows the recommended size of wire based on Davis-Bournonville practice for welding steel up to and including 1 inch thickness.

The diameter of wire should be chosen with reference to the thickness of the joint and the size of the tip and the flame. A small wire is not suited to the welding of a heavy plate. In the first place an excessive length is required to fill the vee and in the second place the small diameter wire exposes a larger surface proportionally to the oxidizing influence of the flame than a large one. The diameter of the wire should be as large as the puddle will melt freely. If too large a wire is used the heat abstracted from the puddle will tend to freeze it and difficulty will be had in maintaining it in the proper state of fluidity. Hence, a welder must always choose the welding rod for a given job strictly with reference to the thickness of the plate and the size of the vee.

Cast iron welding sticks are furnished in $\frac{3}{16}$, $\frac{1}{4}$, $\frac{3}{8}$ and $\frac{1}{2}$ inch diameters, and aluminum welding sticks—the cast metal—are furnished in 12-inch lengths, $\frac{3}{16}$ to $\frac{1}{4}$ and $\frac{5}{16}$ inch diameters. The cast rods or sticks are used on cast aluminum particularly, while the drawn rods or wire are preferable for welding rolled aluminum sheets such as are used in the manufacture of teakettles and other kitchen utensiles.

Brass and bronze are welded with cast welding sticks and drawn bronze rods. These are furnished in a variety of diameters and length. Brazing wire in the smaller diameters is furnished in coils while the larger diameters are furnished in 36-inch lengths. The same applies to wire for copper welding. Brass wire is not a suitable adding material for welding as it contains a large percentage of zinc. This burns out at a comparatively low temperature, making dense white fumes. The

fumes are poisonous to the operator, and the welding material is defective in strength when the zinc has been burned out. Bronze rods produce a much stronger joint and are less harmful to the operator.

Malleable Cast Iron should be Brazed

Malleable cast iron is a white cast iron which has been subjected to an annealing process that converts the outside shell to a grade of iron having some of the characteristics of wrought iron; a malleable casting will bend before it breaks. Malleable iron is used where ordinary gray iron castings are not safe on account of heavy loads, and shock. It is not good practice to weld malleable iron parts because the joint produced will be one of cast iron. Even if steel adding material is employed the joint will necessarily be weak because the fused edges of the casting are changed from malleable iron to a poor grade of cast iron when held under the torch. Hence, a welded malleable casting is likely to be unsatisfactory. In the first place, you have a casting made of malleable iron because the situation requires greater strength than can be gotten in a gray iron casting and in the second place, the malleable casting having broken, shows that the stresses are too great even for the malleable part. It is, therefore, useless to restore the broken casting with a welded joint inferior in strength to the original structure.

When the welder is confronted with a broken malleable part he should recognize the metal and proceed accordingly. The best practice is to braze the joint with bronze welding wire and an approved brazing flux. A properly brazed joint in malleable cast iron will be as strong as the original section of malleable iron. It is not necessary when brazing to raise the metal to the melting point. Hence, the malleable characteristics of the iron are left unchanged.

Function of Fluxes

When a tinner solders a joint he uses rosin or acid to make the solder flow smoothly. If solder is dropped on an unclean metal surface it will remain in isolated drops and refuse to amalgamate with the metal beneath. The reason for this is

the thin film of oxide which prevents intimate contact. The tinner's acid dissolves the oxide and permits the molten solder to unite with the surface beneath and cover it smoothly. The rosin acts as a protective, preventing the formation of oxide and facilitating the flow of solder. Metals in the molten state have a strong affinity for oxygen, as is shown by the oxide film or dross that quickly forms on the surface. If the surface of molten metal is covered with some substance that protects it from air, oxidization will be greatly reduced or eliminated entirely. Hence, in welding materials that are easily oxidized it is advisable to use a scaling powder or flux which protects the metal and makes the union of the fused metal easy.

The function of flux in general, therefore, is to prevent the formation of oxides and to eliminate oxides already formed and to act as a solvent or loosener of trapped oxide and slag. Cast iron for example, has a strong attraction for oxygen when molten and the use of a scaling powder or flux will be found necessary. Cast iron melts at a lower temperature than iron oxide and unless the oxide is dissolved it will be found impossible to produce a sound weld. The metal will stand in drops and act much the same as solder on an unclean tin surface. The addition of a little scaling powder acts like magic causing the drops to coalesce and unite with the parent metal.

Some of the troubles caused by the presence of oxide are eliminated by increasing the heat sufficient to melt the oxide film. Steel and wrought iron when melted tend to form oxide the same as cast iron but the higher melting temperature required melts the oxide and so it gives little or no trouble. However, flux is not amiss on steel sometimes, especially if the carbon content is rather high, and a first-class smooth job is required.

Composition of Fluxes

The blacksmith from time immemorial has used common river sand or silica when welding wrought iron. The silica melts and forms a coating of molten glass which acts as a protection for the white hot iron and prevents it being oxidized by the blast. Protected by this coating the iron may be safely raised

to the welding temperature without burning. It must be knocked off when the iron is ready for welding and this is accomplished by giving the bars a smart blow upon the anvil.

There are many other materials that can be used for fluxes in welding the various metals and some welders compound their own fluxes, but in general the use of homemade fluxes is not wise. Powdered borax is commonly used for brazing brass, bronze and copper but unless calcined it gives much trouble by bubbling and frothing due to the contained water of crystallization. Preparations are available at somewhat higher cost, which work well and save time, trouble and annoyance. These are important factors in efficient welding. The work should be made as easy as possible and false economies should be avoided. Many a penny is saved at the spigot while dollars are lost at the bunghole in the welding shop. The chief items of expense are the gases and labor. Make labor efficient and save gas. A few cents saved in a shop compounding a flux may be lost many times over in the added cost of welding. Hence we do not advise the manager of a welding shop giving much attention to so-called cheap compounds for scaling and fluxing. "It is better to be sure than sorry."

The proper preparation of a flux requires careful proportioning of the material and intimate mixing with machines. The ingredients must be finely pulverized and intimately mixed in order to produce a flux that will be uniform in its action on the fused metal. An improperly mixed flux is uncertain in its effect as the chemical action on the metal will depend on the precise composition of the portion in contact on the instant. If it happens that a certain ingredient is in excess it might well produce an indefinite or detrimental action. Hence, the matter of mechanical preparation of the flux is often as important as the chemical make-up. The chemical action cannot be predicted unless it is known that the materials are thoroughly incorporated and applied in uniform proportion, no matter whether a large or small amount is used.

The use of fluxes is strictly necessary on many kinds of welding and the proper flux should always be provided but the oxy-acetylene welder should avoid placing too much reliance in fluxes and scaling powder, as cure-alls for welding troubles.

Proper flame adjustment and torch manipulation will avoid many of the troubles that unskilled welders attempt to overcome by the liberal use of fluxes. The envelope of the neutral flame is, in itself, a protection to the molten metal, and if the flame is properly adjusted and the joint is welded quickly without exposing the puddle to the oxidizing atmosphere, the need of flux will be reduced to a minimum. The skilled welder uses but little flux but he uses it intelligently and chooses the right kind for the job in hand.

Questions

1. What is the function of a flux?
2. What is a common flux used by blacksmiths?
3. What is the effect of carbon on the melting point of steel?
4. Why should a welding rod be low in carbon content?
5. What is the character of a gas welded joint?
6. Why should the welder avoid the use of rusty welding rods?
7. What is the difference between adhesion and cohesion?
8. At about what temperature does Swedish iron fuse?
9. Why is it bad practice to use commercial wire for adding material?
10. What is the probable result of using ordinary cast iron welding rods for cast iron welding?
11. Why should malleable cast iron be brazed?
12. What material should you use for brazing malleable iron?
13. It is necessary to use flux when welding mild steel? Why?
14. Why is flux necessary when welding cast iron?
15. Why is it poor economy to make your own flux?

Notes

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DAVIS-BOURNONVILLE
OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

SHAPE OR MOLD WELDING

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

Form 388

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SHAPE OR MOLD WELDING

Use for Salvaging—Shape Welding—Mold or Dam Welding—Use of Carbonite Rod—Replacing Broken Gear Teeth—Carbonite Molds—Restoring Worn Journals.

What mechanic has not wished for a "putting-on tool" when he has turned a piece too small or has planed off too much by taking an injudicious depth of cut? The putting-on tool was a figment of the imagination and a practical joke until the oxy-acetylene torch came into use. It made the impossible not only possible but practicable.

Use for Salvaging

It is now a not uncommon practice to salvage parts that have been spoiled by improper machining or that have been reduced by wear. Worn journals can be restored to the original diameters by welding a thin layer of steel to the surface. Of course, the welded metal on the journal must be turned and polished in a lathe before it can be used. There are many other machine parts that can be made whole again by building on adding material and machining to the required dimensions and finish. One of the most frequent accidents to machinery is the breaking of gear teeth. A gear with a broken tooth is practically useless, and it may represent an investment of several hundred dollars. Ordinary methods of patching in a new tooth are mostly worthless as a patched tooth will have so little strength that it will be broken out as soon as an extra heavy load has to be transmitted. A tooth built up of adding material is as strong and durable as the original if properly done.

One of the interesting and unusual applications of the oxy-acetylene torch in this line is depositing a coating of cast iron on the seats of steel poppet valves used in gas engines. Cast iron resists the heat and abrasive action of exhaust gases superior to steel. The cast iron forms a seat on the poppet valve equal to that in the cylinder casting, and outlasts several steel seats, thus reduc-

ing the cost of upkeep. The cast iron coating of course must be accurately finished the same as the solid steel valve but being much more durable the cost is well repaid. Steel plates that have been punched incorrectly may be restored at low cost when a few holes of small diameter are out of place. The welded sheet may then be correctly punched and used without fear that the restored parts will fail in use. This operation is not, of course, shape or mold welding but it comes under the general head of salvaging manufactured parts or making old boiler plates useful for new purposes.

Shape Welding

There are two distinct kinds of shape welding, one being accomplished by torch manipulation alone and the other by the aid of dams and molds of high heat resisting material. A boss can be built upon the face of a gray iron casting of any size and height by fusing on adding material in the quantity required. It is not difficult for the experienced welder to keep the margins from sloughing off or to control the shape of contour to simple forms. It is done by graduating the heat so that the molten metal at the edges is near the freezing temperature and flows only when the flame is held close. The moment it becomes too fluid the flame is whipped off and directed upon a colder part. The same manipulative skill is required as in finishing the end of a joint square. Less heat must be applied than in the center when finishing a joint and the torch is whipped up whenever the metal gives signs of breaking down and overflowing the edge.

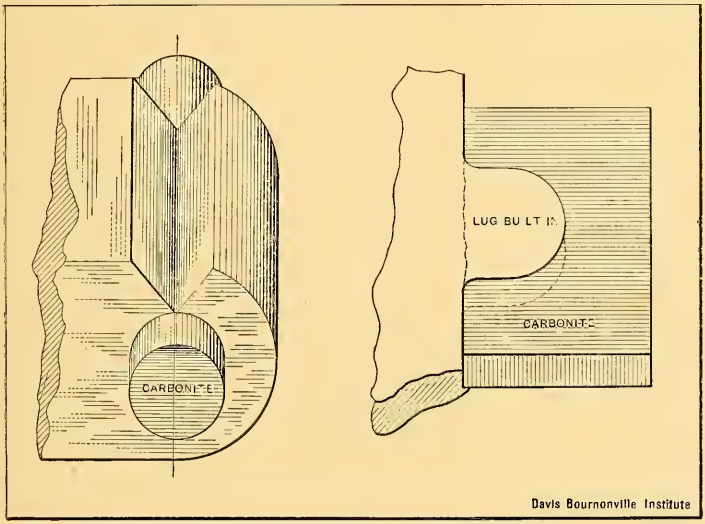
Bosses can be built not only vertically but horizontally and at any intermediate angle at will. The usefulness of boss welding in repair work is obvious, and welders should practice it not only to acquire skill in forming bosses but to perfect themselves in the art of finishing welds square and in a workmanlike manner.

Mold or Dam Welding

When a new lug, ear or other part is required to replace one broken from a casting, it is generally advisable to make use of a mold or dam of some material like carbon blocks or carbonite

which resists the heat of the torch flame and which can be readily cut, carved, sawed and drilled. Carbonite possesses these qualities in a most satisfactory degree, and is used generally for shape welding and also as a retaining wall for difficult side seam and vertical seam welding.

Suppose a lug has been broken from a casting and lost. To replace it is a matter of merely providing a carbonite mold of the shape required, open at the top and placing it against the casting with the opening opposite the break; the block is weighted down



FIGS. 1 AND 2. USE OF CARBONITE ROD AND BLOCK FOR SHAPE WELDING

and the welder proceeds to fuse the face of the casting and supply adding material until the mold is filled to the required height. If the lug was recovered it is often cheaper to build up a new one in a mold than to weld the old one in place. The preferable practice depends on the size and other conditions.

Preheating the casting is advisable in order to prevent excessive expansion and contraction stresses, and the lug and casting should be covered with asbestos paper or other insulating material in order to prevent rapid cooling.

Use of Carbonite Rod

Carbonite is supplied in blocks or slabs, in various thicknesses from ⅜ inch to 1 inch, in width up to 6 inches and lengths of 36 inches. Rods of the same are furnished in diameters of ⅜ inch to 1 inch, inclusive. Carbonite rods are used to fill holes when welding radiating cracks. If properly placed the walls will maintain their shape and thus render boring or reaming unnecessary. It will burn away slightly so that a little filing only will be required. In fact the judicious use of carbonite rods will often make welding feasible that otherwise would be impracticable on account of cost of subsequent machining.

Replacing Broken Gear Teeth

Broken gear teeth may be replaced successfully on all kinds of gray iron and steel gears but it is not advisable to attempt the replacement of the teeth of motor car transmission gears except as an emergency repair. These gears are generally made of alloy steel and specially heat-treated to give them toughness and durability, and unless the welded teeth are made of the same metal and heat-treated the job will not last. However, there are many other broken gears that can be repaired with uniform satisfaction.

The practice of replacing broken teeth depends on the gear and local conditions. A gray iron gear with cast teeth can be repaired by building up a new tooth alone, using carbonite blocks in the adjacent spaces to hold the new metal closely to the general thickness of the old tooth. Care must be taken in preheating not to crack the rim and the welded tooth must be protected from cooling down too rapidly when complete. When the welding is finished and the casting has cooled down the tooth is ground to shape with a portable emery grinder or chipped and filed to a templet.

If the gear has cut teeth and a gear cutter of sufficient capacity is available the preferable practice is to build in the broken teeth and adjacent tooth spaces solid with new metal, and then cut two spaces on the gear cutter. This should produce a solid well formed tooth. An alternative method less expensive but not so likely to produce a good job is to build in the tooth with

carbonite blocks alongside, and finish with the gear cutter. The difficulty is that the cutter is at disadvantage in cutting, having to cut metal on one side only. Springing and chattering are bound to result making considerable hand finishing necessary.

Carbonite Molds

In an emergency small castings may be made entirely with adding material and a mold formed of carbonite blocks and rods. In some cases adding material can be saved by using chunks of scrap cast iron to fill the larger spaces. The welding stick is then used to fill in and join the parts only. Of course, resort

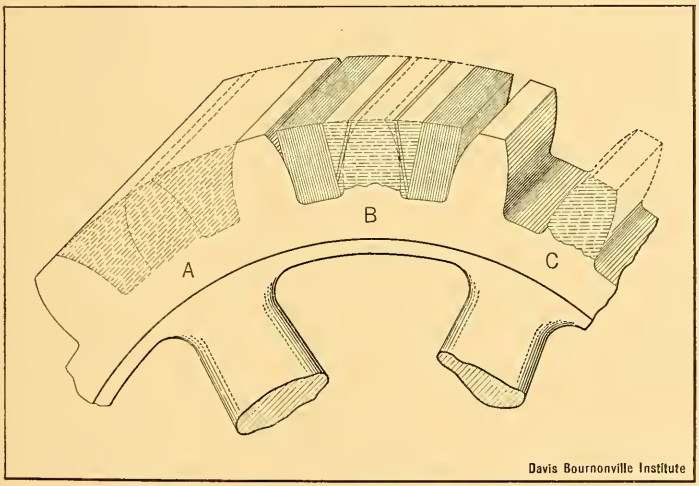


FIG. 3. RESTORING BROKEN GEAR TEETH WITH AND WITHOUT CARBONITE BLOCKS

should never be made to this method except when the need of the part is so great that the cost is a secondary consideration.

In conclusion let us impress the value of carbonite in the welding shop again. It is easily cut or carved to any shape required and having high heat-resisting quality it can be used in welding with general satisfaction. It can be turned in the lathe, planed, drilled, cut with a hacksaw, carved with a knife, filed with a rasp and, in fact, can be easily shaped to any form required with ordinary tools. Being supplied in slabs of different thick-

nesses and in rods of various diameters the welder can usually select the commercial size that most nearly meets his needs and thus save considerable unnecessary labor. When used for plugging a hole to support metal needed to replace a broken away section no allowance need be made in the carbonite for finishing. It will burn away sufficiently to provide enough excess metal in the hole for filing smooth and true with the remainder. Often it is used to protect threaded holes close to sections that must be welded. In that case the carbonite should be fitted as closely as possible. If it fits so closely that a thread is cut in it while screwing into place so much the better.

Restoring Worn Journals

When restoring a worn journal the shaft should be preheated and kept hot throughout the operation. It should be supported on vees so that it can be turned around as the building on proceeds. The adding material should be laid in thin strips lengthwise, taking care to secure penetration into the shaft and blending with the strip already laid. If skillfully done the journal should not be sprung or distorted so much that an ordinary finishing cut on the journals will not bring them true. But a restored shaft should be tested on centers for truth before starting to turn, and if it runs out it must be straightened first with a shaft straightener.

Questions

1. Can you give a good example of the use of the oxy-acetylene torch as a "putting-on" tool?
2. What precaution must be taken when restoring worn shaft journals to the original diameter?
3. How would you proceed to restore a broken tooth in a cast gear?
4. In what respect does the practice of restoring cut gear teeth differ from that followed on cast teeth?
5. Which is the best practice to follow when restoring broken teeth in cut gears—building up one tooth alone, or building the tooth and filling the adjacent tooth spaces with adding material? Why?

6. What do you understand by shape welding?
7. How is it possible for a welder to build up a boss with a torch?
8. Do you see in boss welding the same manipulative skill required to finish the end of a joint?
9. Which is preferable when restoring a broken lug, to build up a new lug of adding material or weld on the old one?
10. What material is recommended for a mold or dam when building on a lug or gear?
11. Why is it necessary to use a material of high heat-resisting quality?
12. What form of carbonite is useful when welding a rack running into a finished hole?
13. How would you proceed to build up a worn journal?
14. How would you proceed to protect a threaded hole when welding close by?
15. Mention an example of building up with adding material to improve the wearing quality of a bearing or seat.

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DAVIS-BOURNONVILLE
OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

WELDING DISSIMILAR METALS

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WELDING DISSIMILAR METALS

Difference Between Autogenous Welding and Soldering—Metal of High Melting Temperature Should be Fused First—Welding Steel and Copper—Welding Machinery Steel and Tool Steel—General Rule for Welding Dissimilar Metals.

It is a remarkable fact that the oxy-acetylene torch can be used successfully for welding practically all metals. Cast iron, steel, wrought iron, aluminum, bronze, copper and many alloys can be welded effectively. Some metals weld easier than others, but practically all can be fused and soundly united by welders who know how to use the torch and adding materials. Not only can all the commercial metals be welded, but combinations of dissimilar metals may also be welded satisfactorily; it is a matter of daily practice to weld steel to cast iron and steel to copper.

Difference Between Autogenous Welding and Soldering

The fact that dissimilar metals also can be successfully welded is one of the differences between autogenous welding and soldering. Soldering in general must be practiced on similar metals or metals whose specific heat and amalgamating temperatures are nearly the same. Some metals, aluminum especially, cannot be soldered at all, or only with great difficulty. There are aluminum solders and workmen who can solder aluminum, but most aluminum soldered joints have a very disagreeable way of parting company after a few weeks. This action is ascribed to electrolysis in the joint which eventually disintegrates the solder and causes the separation. The most successful method of uniting aluminum is by autogenous welding, using the oxy-acetylene torch; the fused metal runs together, making one homogenous piece.

Metal of High Melting Temperature Should Be Fused First

In welding dissimilar metals it is necessary to manipulate the torch so that the metal of highest fusing temperature is

played on most. The adding material is built up on the metal of the lower fusing temperature, and then is united with the metal of higher fusing temperature. When the fusing temperature of one metal is high and that of the other is low the job offers considerable difficulty and can be successfully accomplished only by one who has acquired considerable experience and skill in handling the torch. It is practically necessary under such conditions to maitain different zones of heat on the two sides of the joint, the highest zone, of course being on the side of the metal having the highest melting temperature. The adding material must be chosen with reference to this condition, and it must be used with skill in order to secure satisfactory results.

Welding Steel and Copper

A not uncommon requirement is to weld copper bonds to street car steel rails. The copper bonds are only ⅜ to ½ inch thick and the steel rail has several times greater cross section. The melting or fusing temperature of steel is considerably higher than that of copper, and in order to make the job commercially practicable the welder must make a study of such welding, and apply his knowledge with his best ability.

Welding is accomplished by first forming the molten puddle on the steel, and inserting the end of the copper bond and fusing it, while protected by an approved copper welding flux. Bronze wire is used for adding material, but little is needed as there should be no attempt made to improve the weld when the copper and steel have united over an area of contact equal to or greater than that of the bond cross section. Then is perfect conductivity assured, and that is the one and sole reason for welding the bonds to the rail.

In passing, your attention is drawn to the fact that the only perfect electric joint is a soldered, brazed or welded joint. An electrical connection made by a mere contact is likley to offer high resistance to the current on account of the oxide film that quickly forms on the clean, bright surfaces of all commercial metals. These oxides offer high resistance, and may, in time, become so pronounced as to interrupt the flow of low voltage currents entirely. It is not an uncommon experience to find

an electric light bulb, long unused, that refuses to light when the switch is turned on. But loosening the lamp and screwing it into the socket again breaks the oxide film and permits the current to flow through the lamp. Hence, it is obvious that autogenous welding of similar and dissimilar metals has a valuable characteristic for electrical work, requiring permanent connections of high conductivity. The use of aluminum before the war for electrical connectors was becoming quite common, and because of the difficulty of welding aluminum, the oxy-acetylene torch was the favorite means of producing the desired welded joints.

A brass nipple screwed into a steel drum may give trouble by leaking under high pressure and for that reason require to be welded. Of course, the welder will avoid playing the torch flame on the nipple before he has raised the steel to the fusing heat. In fact, the fused steel will act the same as the puddle on the adding material stick; it will melt the brass and unite with it readily especially if a little bronze welding flux is used. The welder should work quickly and as close to the nipple as possible making the weld complete as he goes along. Bronze welding wire should be used to fill the joint and form the fillet. The weld, if made at a low temperature, will have the characteristics of a brazed joint. For most situations this will answer. It has the advantage of not requiring a heat likely to injure the brass.

Welding Machinery Steel and Tool Steel

The influence of carbon in steel is to lower the fusing temperature, the greater the carbon content the lower the melting point within certain limits. Pure iron and mild steel require several hundred degrees higher temperature for welding than high carbon steel and high-speed steel. The danger then in welding tool steel and machinery steel is that the heat required to melt the machinery steel will burn the tool or oxidize it to a degree that renders it worthless. Hence, great care has to be taken to graduate the heat so that fusion without overheating is obtained.

One of the jobs that welders employed in manufacturing shops may be required to do is welding high-speed steel tips to machine tool shanks to form metal cutting tools. The cost of high-

speed steel is from $2.00 to $3.50 a pound or more. A large planer tool may easily weigh ten or twelve pounds, and inasmuch as only a few ounces of steel at the point do the cutting it is practically unnecessary that ten pounds or more of high-priced steel be used as a shank merely to support the cutting tool. A high-speed steel tip welded to a machine steel shank serves the purpose fully as well, and the investment in high-speed steel is reduced 80 or 90 per cent.

To weld a high-speed steel bit to a machine steel or carbon steel shank is not easy but it can be done and done well if certain rules are followed. The first step is to plane the machine steel shank across the end so as to form a notch or shelf on which the high-speed bit will be supported while under the pressure of the cut. The edges should be beveled to an angle of say 55 to 60 degrees or more in order to avoid beveling the edges of the tool bit and wasting the high-priced steel. If the tool is large it is inadvisable to attempt to weld the entire surface of the bit to the shank; it will suffice to weld the edges and depend on the support provided by the notch to carry the thrust on the joint. Preheat the parts and weld with a Swedish iron welding rod, or the adding material recommended by the manufacturers of oxy-acetylene apparatus for the purpose. The welder fuses the machine steel first and "tins" the bit with the iron adding material before undertaking to weld it to the machine steel shank; when the high-speed steel has been "tinned" with the iron adding material it is not then so difficult to unite the iron adding material to the steel shank.

Extra length twist drills are sometimes required for drilling deep holes, and a machinery steel shank must be welded to a commercial twist drill of the desired size. The joint should be scarfed or beveled, making the length of the bevel two or three times the diameter of the drill. A half-round groove should be planed in a carbonite block in which the drill and shank can be laid horizontally for welding. If of small diameter place the parts in the groove so that the bevel of the shank overlaps the drill, and proceed to fuse the machinery steel working on the theory that the heat transmitted to the high-carbon steel beneath will be sufficient to fuse it and produce a weld. Use but little adding ma-

terial at the edges. But if the drill is one-half inch diameter or larger it will be necessary to tin it with adding material before laying the shank in place and the edge of the bevel on the shank must be beveled in the usual manner to let the adding material enter and make a sound union. After welding, the excess metal is ground off to the drill diameter.

General Rules for Welding Dissimilar Metals

In general, the rule for welding dissimilar metals is summed up in a few words, as follows: Fuse the metal of comparatively low melting temperature and coat it with approved adding material; then weld the coated or tinned part to the piece having the higher fusing temperature. Avoid directing the torch flame upon the metal of low melting point more than absolutely necessary to tin it and secure a union with the adding material.

When care is taken to do a good job of coating and the adding material is chosen with reference to the characteristics of the two metals to be welded it is not out of the question to weld metals having quite widely different melting temperatures. Of course, there are practical limitations to what can be accomplished in welding different metals, both on the score of cost and difference in expansion coefficients. It is obvious that long welds cannot be successfully made with two metals having widely different rates of expansion and contraction. The internal stresses produced will bend the welded parts or pull the welds apart. But in welds of comparatively small area or length the stresses thus produced are small and negligible. Tack welding may sometimes be used with satisfaction on long welds if not subjected afterwards to great temperature variations. Tack welds do not require preheating and fusing throughout the length of the joint.

Questions

1. What metals can be welded with the torch?
2. What is the rule regarding the use of adding material when welding on metal?
3. Why is it generally difficult to weld dissimilar metals?
4. In what respect does welding differ from soldering?

5. When welding two dissimilar metal parts which one should be welded first?
6. What is "tinning" when welding dissimilar metals?
7. Which metal should be "tinned" when welding?
8. What is the effect of carbon on the melting point of steel?
9. Which melts first, mild steel or high carbon steel?
10. What is the danger when welding mild steel and high carbon steel?
11. How would you proceed to weld a high-speed steel bit to a machine steel shank?
12. Is it advisable to attempt to make long welds between dissimilar metals? Why?

DAVIS-BOURNONVILLE
OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

GAS WELDING MACHINES

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JERSEY CITY, N. J.

Form 390

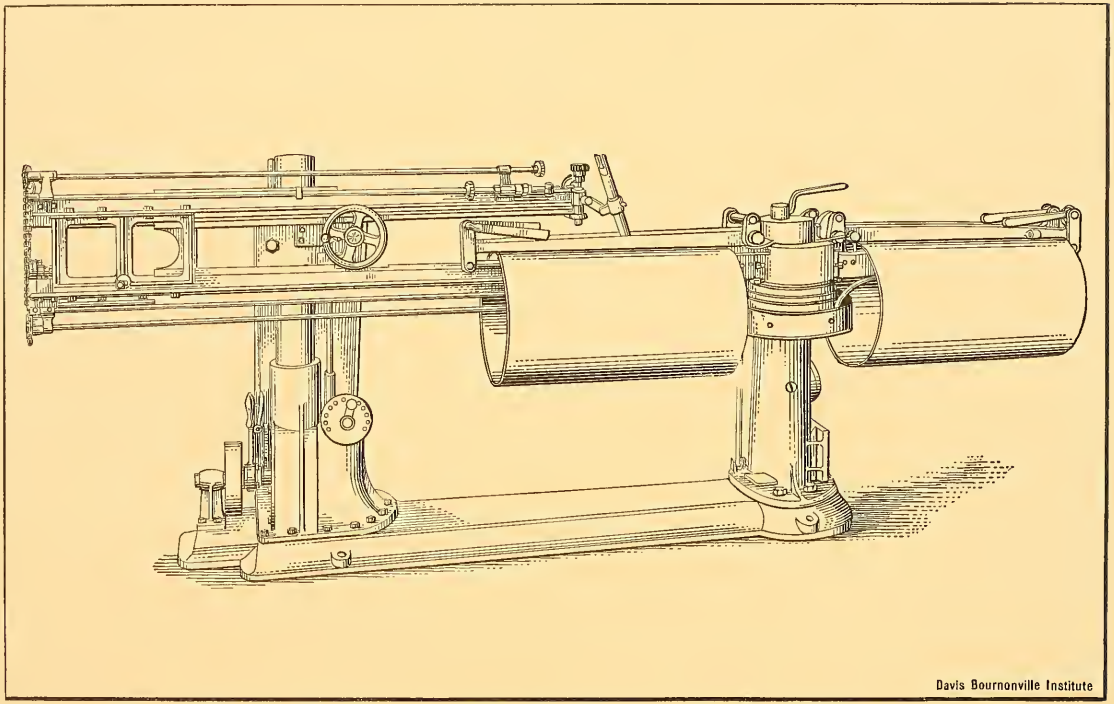

FIG. 1. THE DUOGRAPH WELDING MACHINE FOR WELDING DRUMS, BARRELS, TANKS, CELLS, ETC.

GAS WELDING MACHINES

Hours of Practice Required to Master Hand Welding Torch—Welding Machines Suited for Manufacturing—Gas Welding Machines—Machine Welding Torches—Clamping Work for Machine Welding—Special Welding Torches for Machine Use—Machine Welded Pipe Joints.

Oxy-acetylene welding torch practice requires a high degree of manipulative skill of the welder; he must hold the torch with the tip of the white hot cone close to the work and always far enough away so as to prevent occlusion of gases, but not so far away that the maximum heat is not imparted to the metal just ahead of the puddle. He must always give the torch a continuous motion, either a straight zig-zag or a semicircular zig-zag across the joint, advancing at the same time in the direction of welding as the puddle progresses. With the other hand he must hold the welding rod in a certain relation to the torch and work. When welding aluminum without flux he must frequently pick up the puddling hook, work out the oxide and all the time hold the torch in the proper position.

Hours of Practice Required to Master Hand Welding Torch

It is easy to show a learner how to hold a welding torch and manipulate it but to acquire the skill requires many hours of practice before one is able to follow the directions easily. No one can long work efficiently when under strain, and as it is necessary for the welder to learn to stand easily and operate the torch correctly without giving thought to anything except the puddle and the direction of the welds he must practice torch work daily for sometime before he becomes sufficiently proficient to be put on regular work. The welder who is really proficient picks up the welding torch and goes to work, exercising the same sub-conscious development that enables you to walk, dance, ride a bicycle or skate without balancing effort. Practice only will enable you to develop the master's skill, and

it is essential that you learn the most efficient method at the start and thus avoid falling into bad practice.

Welding Machines Suited for Manufacturing

The hand welding torch and skilled operator must always be used for welding a large variety of shop and field repair and fabricating work. But it is not necessarily the only means available for welding duplicate parts made in quantities. Early in the development of the oxy-acetylene torch practice the possibility of holding and guiding the torch mechanically was recognized and machines were devised for the purpose with a view of utilizing the apparently great possibilities of the gas torch for manufacturing. A description of a machine for gas welding tanks and parts of boilers was published in France in 1907 and other machines for welding had been worked out sometime before.

It is obvious that when parts are to be manufactured in quantities that require welding it is easily within the bounds of possibility to design and build a welding machine to hold the torch in the proper relation and to feed either the work or the torch along at the required rate to produce a perfect weld in thin stock which requires no adding material. Gas welding machines have been applied successfully in the manufacture of pipe, tubing, range boilers, steel barrels, battery boxes, electrolytic cells and similar products made in large quantities. The steel used is thin, generally not more than 3/32 inch thick and requires the use of no adding material. Hence, there is no complication in the machine due to holding and feeding welding rods to the joint. Doubtless, it would be possible to machine weld prepared joints and feed welding rod to the joint at the required rate but so far as known this has not been commercially accomplished. In fact, the possibilities of machine welding have as yet been developed to a comparatively small degree. But it is apparent that special welding apparatus will produce machine welded parts cheaply that are practically impossible of commercial production by other methods. The rate of production is rapid and even if the parts can be hand welded the welding machines do the work so much faster that hand operation is

generally out of the question. Moreover, a welding machine makes smooth, uniform welds without adding material. A peculiarity of welding machines is that adding material is not required where it would necessarily be used if hand welded.

Gas Welding Machines

Tube, pipe and boiler welding machines have been developed abroad and in this country. The Davis-Bournonville Company builds a number of welding machines among which is the Duograph, designed for the rapid welding of the longitudinal seams of steel drums, pressure containers and smaller parts. The machine comprises a two-arm turret work-holding device with water-cooled clamps for holding the steel sheet firmly in position while welding. The machine is semi-automatic in operation, the torch being traversed by power feed while the operator removes the welded barrel and replaces it with a rolled sheet to be welded on the opposite arm. The carriage supporting the torch is provided with variable feed in order to adapt it to the variable conditions of welding. Obviously, the speed of traverse must be gauged closely in order to weld perfectly, producing neither cold shuts due to excessive speed or burned metal because of too slow speed. One torch only is needed for light machine welding but the carriage of the Duograph provides for the use of two torches, one below and the other above the seam. Both torches are used on the thicker gauges which, of course, can be welded more rapidly and effectively with two torches working on opposite sides than when one torch only is in operation.

Machine Welding Torches

Special forms of torches are used on welding machines, the tips being set in line with the axis of the body or barrel. The head is water-cooled by means of a water circulation system. The water is conveyed to the torch head by one hose and carried away by another. Water cooling is necessary on account of the radiated heat which would make the head so hot that flashbacks would continually interrupt the work. The tips used are special, generally being made to produce a row of flames, or a wide thin flame. The row of flames or the long dimension

of the thin flame, are in line with the joint of course. The thin torch flame is called a ribbon flame.

The No. 1 Duograph which welds a 36-inch seam and handles containers of 12 inches to 36 inches diameter operates at a welding speed of 18 inches per minute and up on No. 16 gauge sheets. Very much faster welding has been accomplished on special tube and boiler welding machines. So rapid is the welding on special machines that pipe and tube manufacture by gas welding is becoming an important industry.

Clamping Work for Machine Welding

One of the difficulties in the way of machine welding by progressive torch action is local heating and resulting expansion and subsequent contraction. Expansion and contraction tend to cause warping and buckling which, perhaps, cannot be permitted in the welded product. The faster the welding is accomplished, however, the less the distortion produced, and thus the effort in designing welding machines is to provide for as rapid welding as possible for two very good reasons; the first being that just mentioned and the second, of course, being greater production and reduced cost.

The distortion produced by the welding flame is also minimized by firmly clamping the sheets each side of the seam close to it. When thus firmly held by water-cooled clamps the sheet metal expansion will be chiefly toward the joint thus having the effect of filling the joint with adding material produced by the parent metals. The longitudinal expansion is slight and hence warping troubles are largely minimized.

Special Welding Torches for Machine Use

Other forms of welding torches developed greatly increase the speed of welding but they are generally highly special and may not particularly interest the hand welder but although you probably will never do machine welding it is highly desirable that you know something of the great manufacturing possibilities of the oxy-acetylene machine torch. Remember, that the manufacturers of welding apparatus are constantly improving their products and that many valuable helps come to men who have ideas of their own or who have been forced to resort

to peculiar methods in order to accomplish difficult welding. The wide-awake welder will study the principle of the torch not only when operated by hand but when mechanically supported and guided. This is an era of automatic and semi-automatic ma-

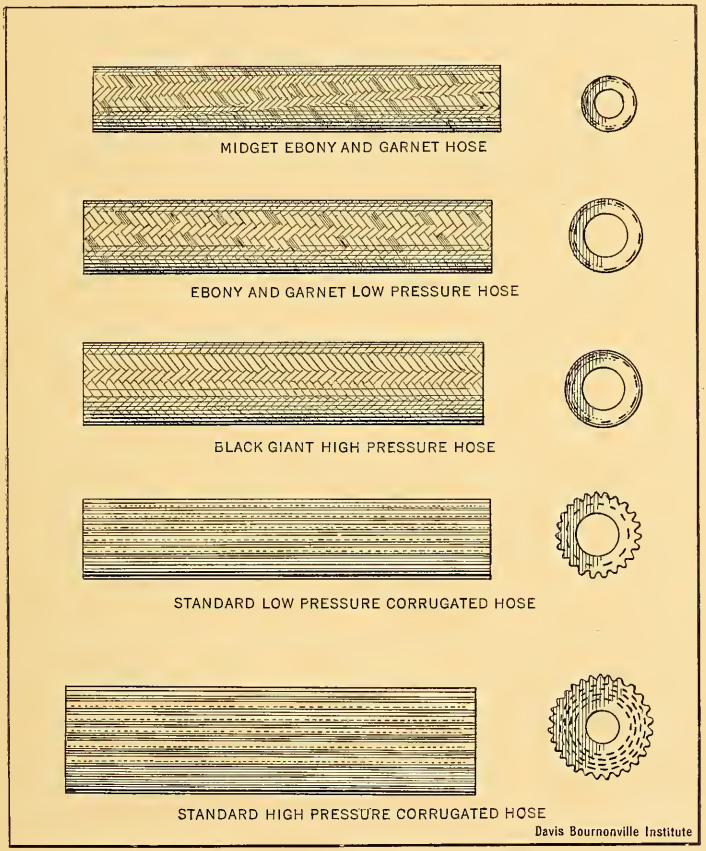
MIDGET EBONY AND GARNET HOSE
EBONY AND GARNET LOW PRESSURE HOSE
BLACK GIANT HIGH PRESSURE HOSE
STANDARD LOW PRESSURE CORRUGATED HOSE
STANDARD HIGH PRESSURE CORRUGATED HOSE
Davis Bournonville Institute

FIG. 2. HOSE FOR HAND AND MACHINE WELDING AND CUTTING TORCHES.

chinery and oxy-acetylene welding and cutting apparatus will doubtless be greatly developed and improved and many applications be made that have not yet been thought of. The reconstruction of the world following the war gives the general salvaging of machinery an economic aspect that it never had before.

Machine Welding Pipe Joints

Oxy-acetylene welded pipe joints in city industrial plants are no longer a novelty but, nevertheless, comparatively little pipe has been welded to that which will eventually be welded when all the advantages of welding practice are more fully

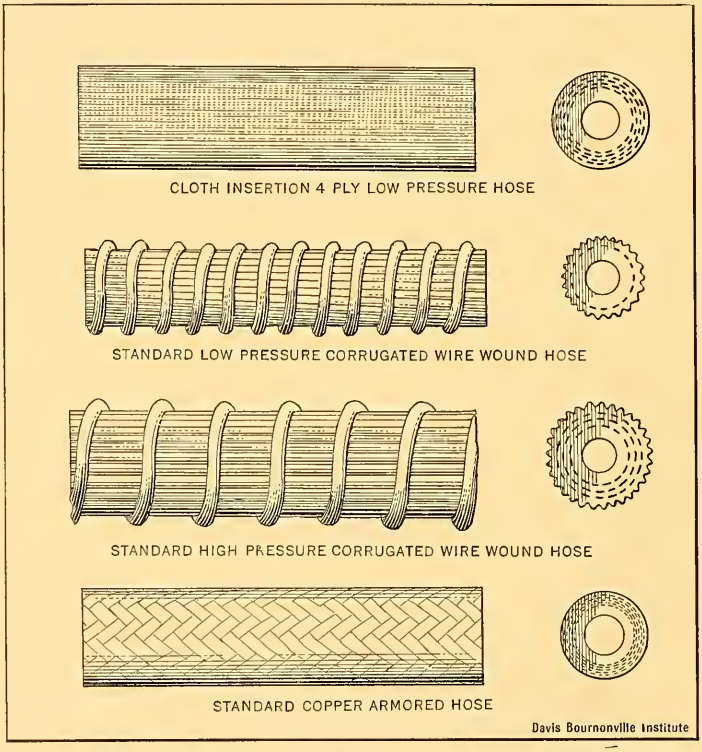
CLOTH INSERTION 4 PLY LOW PRESSURE HOSE
STANDARD LOW PRESSURE CORRUGATED WIRE WOUND HOSE
STANDARD HIGH PRESSURE CORRUGATED WIRE WOUND HOSE
STANDARD COPPER ARMORED HOSE
Davis Bournonville Institute

FIG. 3. HOSE FOR HAND AND MACHINE WELDING AND CUTTING TORCHES.

realized by city and industrial engineers. Ordinary screw pipe connections are unsatisfactory for two principal reasons. First and most important is the fact that a screwed pipe joint is always likely to spring a leak. If the leak develops in a long line it is generally a matter of considerable difficulty to disconnect and make the leaky joint tight. In the second place, screwed pipe joints are costly, the ends of the pipe must be

threaded in pipe machines and the couplings made and threaded also. But this is not the end of the expense. The job of screwing pipe together is slow, hard and laborious, especially on pipe of large diameters.

Special gas welding machines have been developed for welding pipe that operate with wonderful speed and efficiency. The machine embraces the pipe at the joint and directs a ribbon flame against the joint all around the circumference at once. Fusion and welding takes places in a few seconds. Means are provided for pulling the pipe ends firmly together and upsetting them slightly when the metal reaches the fusion stage, thus making a perfect weld slightly thicker at the joint than in the unwelded parts. Welded joints make a pipe line one long pipe without a coupling, union or other other connection to leak and give trouble. The welds are quickly made with the gas welding machine at a comparatively small expense and as the weld adds practically nothing to the pipe diameter there is no interference with the application of pipe coverings. This is an important consideration in the erection of steam lines which must be heat insulated. The advantages of a smooth non-leaking pipe line offset many times the apparent disadvantage of having a pipe that cannot be taken apart except by cutting. While is is true that the plant engineer ordinarily has in mind the question of possible disconnection, the need of providing for easy disconnection is largely eliminated with welded pipe. In case welded pipes must be disconnected the cutting torch, of course, makes easy the removal of a section when required for changes. Hence, it may be that the pipe fitter of the future will use welding and cutting torches of common and special forms more than the time-honored pipe tongs and pipe cutters.

Pipe welding is only one of the many applications of gas welding torches. It is quite possible that the riveted seams in steam boilers and other pressure containers may be displaced eventually by welded joints. The possible savings of time, labor, material and weight are important considerations but boiler seam welding can be realized only with the use of welding machines because hand welding is generally too slow and inefficient to permit of its use on steam boilers in competition with riveting.

Questions

1. Are welding machines suited to repair work? Why?
2. For what general classes of welding are welding machines used?
3. What is the general difference between a machine welding torch and a hand welding torch?
4. If you were given a contract for laying 5000 feet of 2-inch pipe in a skating rink what methods would you seriously consider for uniting the pipe?
5. Is adding material used in welding machines?
6. Is a machine torch zig-zagged across the joint?
7. Why are special tips used on welding machines to give a ribbon-like flame?
8. Why is it necessary to provide water cooling for machine welding torches?

Notes

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DAVIS-BOURNONVILLE
OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

TESTING WELDED JOINTS

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

Form 391

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TESTING WELDED JOINTS

Surface Indications of Welding Jobs Uncertain—Test of Oxy-Acetylene Welded Joint Training and Character of Man Who Welded It—Effect of Testing Welds—Welder Like a Bricklayer, As He Must Begin on a Sound Foundation—Factors of Safety—Efficiency of Welds—Pulling and Bending Tests —Etching Welds.

Welded joints, whether made by a blacksmith, an electric welder or an oxy-acetylene torch operator may be very fair on the surface and rotten at the core. When a weld is finished an inspector can check its integrity by the surface appearance only. If the surface appearance is good the conclusion is naturally drawn that the whole weld is sound, but the conclusion may be far from the fact. There is no practical method available by which the integrity of any weld can be proven except by breaking it or pulling it apart. Of course, any method of testing welds that requires their destruction is out of the question for commercial work.

Test of Oxy-Acetylene Welded Joint Training and Character of Man Who Welded It

The test of the weld is the character of the man who made it. Hence, the testing of welds must resolve into a matter of training welders to make sound welds and then depending on their sense of honesty to follow the methods taught when doing commercial work. In the workroom exercises you have noticed that you have been required to break apart almost every weld made, and to note the defects common in the work of oxy-acetylene welding beginners, and to distinguish between good and poor penetration. You were required to weld test pieces and pull them apart in a testing machine. You learned how strong a weld actually is when subjected to the test that admits of no deception.

What has been the result of this constant testing of welds? You have learned to be your own severest critic and to correct

faults of practice that produce poor work. You have learned to instinctively realize when you are getting penetration and perfect union. You know when you have finished a seam whether the weld is sound or otherwise, because you have welded similar pieces and tested them to destruction. The laws of nature work always the same, and if you have followed methods which experience has proved to be sound, you are bound to get good results. Therefore, the practical test of an oxy-acetylene weld is the character and training of the man who made it.

Effect of Testing Welds

When you made your first welds in thin steel and broke them apart you doubtless were much surprised to see how easily they parted company. The weld was mostly camouflage; the material was united in spots only and along the edges. It was not soundly welded in the center.

These defects were not at all strange to your instructor. He knew that you were a beginner and that you would inevitably make the same mistakes that all make when learning the art. There are many things to master in oxy-acetylene torch practice, and it is too much to expect that any ordinary human being will master all of them at once, and apply the principles correctly. He has to learn by experiences and practice to hold the torch in the correct position and give it the proper motion so that he can concentrate his mind on producing a puddle and feeding it with adding material. At first you made the mistake of melting your adding material with the torch flame and produced welds containing cold shuts and piled up metal. You finally learned that the puddle must melt the adding material, which means that the torch flame may be so held as to produce the fusing temperature in the metal. If the puddle is hot enough to melt the adding material, you may be sure that it is hot enough to fuse the sides of the plate and produce intimate union when cold.

Welder Like a Bricklayer as He Must Begin on a Sound Foundation

As you improved in practice your welds became stronger and you learned that you were like a bricklayer—you have to

work up from the bottom, begin on a sound foundation, and every layer has to be deposited with care. If you start right at the bottom and work right clear up to the top you must produce a sound job, and there can be no question but that the weld will be strong.

When your welded joints were tested you found that some of the best appearing joints failed much easier than some of the others that were rougher and not nearly so attractive. The oxy-acetylene welded joints are like men. Some men have smooth, polished exteriors but are rotten at the core; they have little strength of character and their principles are bad. Other men of rougher exterior may be sound and dependable. Their word is good as their bond, and if they undertake to work for an employer they give him the best service they are capable of rendering. But do not assume that it is not good practice to make smooth, fine appearing welds. On the contrary, it is highly desirable but we want you to learn first of all to make a sound weld no matter how it looks, and then to make a sound weld of good appearance.

Factors of Safety

Fortunately, for much welded work, the factor of safety is high. By factor of safety we mean that the actual load or stress that a part must sustain is a fraction of the actual strength. The actual strength is several times the strength required. For example, pressure containers like steam boilers are usually made of steel plates having five times the highest tensile stress that will be imposed by normal steam pressures. Then the factor of safety is five; that is, the shell could be subjected to a pressure five times the normal before it would give way. If the working pressure were 150 pounds per square inch the boiler might not explode until the pressure runs up to 750 pounds per square inch.

So it is in general with machine members and other parts that fail in service due to accident. They were designed with liberal safety factors to provide for several times the normal load but shock, wear or accident has caused failure. The welder's job may last long even though the weld is actually weaker than the original part, but he should always try to reach 100 per cent efficiency.

Efficiency of Welds

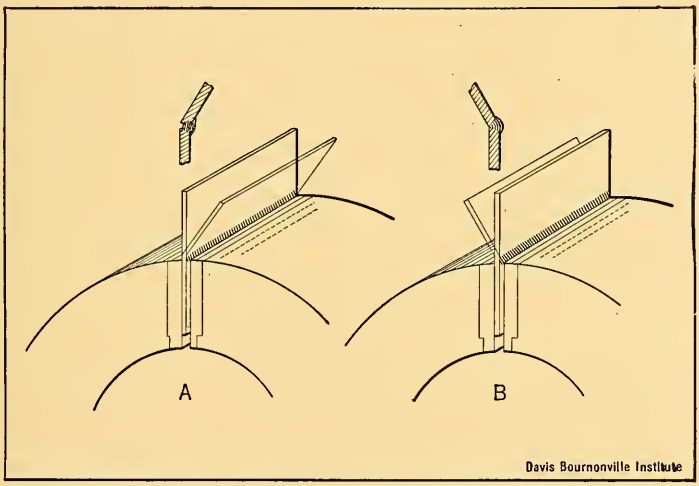
When making welds for tests do not deceive yourself or anyone else by making the welded part thicker than the remainder of the bar. In practice it may be desirable to increase the cross section of the welded part in order to insure the maximum strength, but when you are welding to test your efficiency be frank with yourself and build up the joint to the thickness that when smoothed off its dimensions will be the same as the bar and no more. Then, when the bar is pulled in the testing machine you will know definitely what the percentage strength of the weld is.

By 100 per cent efficiency we mean that the welds will be as strong as any other part. A mild steel bar ½ inch thick and 2 inches wide should have an ultimate strength of about 60,000 pounds. Now, if you are ever able to weld a steel bar ½ inch thick and two inches wide, making the weld no thicker than the bar and have it withstand a pull of approximately 60,000 pounds, you have reached 100 per cent efficiency. The bar will break in some other place as quickly as in the weld. However, 100 per cent efficiency in an oxy-acetylene welded joint or any other is too much ever to expect. If you get up to about 95 per cent you will be doing very well indeed, and that is about as much as any one can reach. The welded joint is built up of fused material and, of course, fused metal is never as strong as the rolled metal of the same grade.

Pulling and Bending Tests

Pulling a welded joint apart in a tensile testing machine determines the strength of a weld under direct pulling stress. Many welded joints show a high tensile strength even when composed largely of brittle adding material. A brittle metal like cast iron even may develop comparatively high tensile strength when pulled apart under favorable conditions. The tensile or pulling test is not always, therefore, a dependable test of welded joints, especially if it is likely to be subjected to alternate bending stresses. The shell of a pressure container like an air receiver may be subjected to many slight bending stresses due to alternate filling and discharge. A welded longitudinal joint in such a container must be free of brittleness.

Bending a welded steel bar is a more severe test of the integrity of the weld than the pulling test. If the adding material has been slightly oxidized and made brittle the bending test will disclose it, and if the penetration is poor the defects will be made apparent. You will find decided difference in the strength of welded joints depending on which way you break them apart when held in the vise. If you break a prepared joint weld apart so as to tear the metal on the top side of the joint apart it will generally offer considerably more resistance than when broken in the opposite direction. Hence, when testing thin welded specimens i



TESTING STEEL PLATE WELDS IN THE VISE "WITH THE WELD" AND "AGAINST THE WELD"

the vise you should put them in the vise jaws with the lower side toward you. Then the hammer blow will stress the lower part of the weld most and thus give you an excellent test of penetration. If you always test the other way you may deceive yourself because you are not giving a bending test that brings out the defects of penetration.

The bending test is crude but effective for rough and ready comparison, and is excellent for beginners. The pulling test in a tensile machine has the advantage of giving the stress in pounds

required to produce rupture, and a series of welds can be pulled apart and the data recorded for future reference. The bending test made in a vise gives you no figures for record. Bending tests, however, may be made in the testing machine by reversing the machine and supporting the specimen on blocks a certain distance apart, and applying the load in the center over the weld. The pounds pressure applied, the distance between the supports, and the angle or drop in inches at which the weld gives way should be recorded.

The vibration testing machine also provides means for making bending tests and giving a record that is useful for comparison now and in the future. The vibration machine holds the sample firmly at one end in a vise or clamp while the other end is vibrated to and fro a short distance by means of a ram connected to an adjustable crank on a rotating shaft, or an equivalent device. The machine is started and run until the specimen breaks when an electrical apparatus stops the machine. The counter shows the number of vibrations required to break the sample. The amplitude of the vibration can be changed to suit the thickness and length of the specimen to be tested.

Etching Welds

Although it is substantially correct that surface indications are not a true index of the strength of gas welds, there are, nevertheless, certain appearances that on an average do indicate to the trained man what the probable characteristics of a weld tested to destruction will disclose. The welder should, therefore, develop to as high a degree as possible the ability to find surface defects in welded joints and from these defects be able to judge the probable condition of the joint as a whole. The presence of mottled or shiny metal discloses the use of carbonizing or oxidizing flames which mean weak material in the joint. Irregular welding and filling are evidences generally of poor torch manipulation, and probably lapping, cold-shuts and poor penetration will be found by destructive tests. In addition to destructive pulling or bending tests the practice of etching the end of the joint of test specimens will be very useful in educating a welder to determine the probable defects from surface indications.

To etch a weld the specimen should be cut across the joint and the surface should be filed, polished and buffed perfectly smooth. It is then corroded with an etching fluid suitable for the metal and after a few seconds it should be cleaned off and examined. A great change will be noticed. The parent metal and adding material will be clearly defined and the line between them will have characteristics that tell whether or not fusion and interlocking were accomplished.

Etching a weld of course tests only the section etched, and proves nothing regarding the character of the joint on either side. But it in general will prove to be a pretty accurate index of what has taken place elsewhere. Breaking welds apart with the hammer, pulling them apart in the testing machine and etching specimens are useful exercises for every welder to practice. They impress on him the fact that sound welds can be produced only by following sound practice. The torch flame must be properly adjusted, the right size tip must be chosen for the thickness of the metal, the manipulation must be even. The welding must not be hurried too fast nor should it be allowed to dawdle along. If the work is hurried the weld will be full of cold-shuts and laps, and if done too slowly the metal is likely to be oxidized and weak.

Questions

1. What percentage of strength may be reasonably expected in a sound gas welded joint in mild steel?
2. What conclusion would you draw if the surface of a steel weld is shiny and covered with oxide?
3. What would you deduce if the weld is mottled and pitted on the surface?
4. How should a welded joint be broken apart in a vise?
5. What is the proper method of breaking apart to make a severe test of penetration?
6. Is the tensile test a conclusive test of strength in a welded joint?
7. What will the bending test generally disclose?
8. What is the effect on a welder of testing his own welds to destruction?
9. Why is a brittle weld unsafe in a machine member?

10. What does the etching test show?
11. How would you prepare a specimen for etching?
12. How should you line up a test bar for welding?

Notes

DAVIS-BOURNONVILLE
OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

BRAZING

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

Form 392

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BRAZING

Brazing an Ancient Art—Bunsen Burner or Torch Effective for Brazing—Close Fitted Joints Important—Malleable Iron Brazed Instead of Welded—Silver Solder.

Uniting brass, bronze, copper and other metals with molten spelter is a very old art dating from pre-historic times. Brazing is soldering, the solder having a much higher fusing temperature than ordinary tinner's solder and being much stronger and harder; it is for that reason called hard soldering. Spelter is another name for zinc but brazing spelter is not pure zinc. The spelter used for brazing is an alloy of zinc and copper, generally in about equal parts, but the ratio is varied to suit the metals to be brazed. Hard solders should have lower fusing temperatures than the metals to be united as otherwise the heat required for melting the spelter is likely also to melt the parts and cause complete failure of the job. This injunction applies particularly to brass jobs that must be done in open forges, gas furnaces or with other sources of heat which cannot be applied locally but must heat the whole piece.

Bunsen Burner or Torch More Effective Than Furnace

When working with the Bunsen burner torch the workman can braze much more effectively than in a furnace as he may direct the flame on the joint only and heat but little more of the adjacent metal than is required to fuse the spelter and produce amalgamation. In general, then, the use of gas burners and torches is preferable for brazing to any other method of heating. Less heat is required and less damage is likely to be done than when the parts must be raised throughout to the melting temperature of spelter. Uniting parts by brazing is an operation that an all-around welder must frequently perform. It is distinctly advantageous to braze often times and should be practiced when the result will be a more satisfactory job than welding.

Joints for Brazing Should Fit Closely

There is one feature of brazing in general that differs radically from the practice you have been taught in regard to oxy-acetylene welding and that is the need of close fitting in order to get best results. When preparing for gas welding you must open up the joint by beveling the edges in order to produce a perfect weld. But in brazing the closer the parts to be brazed are brought together the better the result will be, strange as it may seem. When two parts are to be brazed they should be fitted closely even though it may take considerable filing to accomplish this. For instance, if a steel plug is to be brazed into the mouth of a pipe the scale should be removed from the interior of the pipe, and the plug should be turned or filed to fit closely. Even if you have to drive the plug into the pipe with a hammer do not be afraid that the spelter cannot get in and form a sound joint. It is a peculiarity of molten spelter in contact with hot metal that it will penetrate into the most closely fitted joint. The closer the joint and the more accurate the fit, the stronger the brazing.

Hence, if you are called upon to braze a lug to the side of a frame which has been riveted and the rivets have worked loose, do not attempt to braze the joint before tightening the rivets, if they can be tightened. If the rivets cannot be tightened, draw the lug against the frame as closely as possible by means of a C-clamp and then braze to the frame and around the rivets. You will produce a much better job with a thin filling of spelter than you could possibly get if you tried to fill a gap 1/16 inch wide or more.

Clean Thoroughly Before Brazing

A precaution that must always be observed when preparing for brazing is to thoroughly clean the parts of oil and grease. In the case of a loose lug considerable time may be required to get all the grease and oil and dirt from underneath the pad before you are ready to braze. Use plenty of gasoline or kerosene to clean out the joint and then clamp firmly in place and heat slowly to dry out the joint. If possible, the metal parts in contact should

be brightened with a file to remove all rust and oxide deposits. You cannot possibly produce a good job of brazing when the parts are corroded, rusty and dirty.

Use Wire Spelter for Torch Brazing

When ready to braze the joint should be sprinkled with powdered borax, or better, with an approved brazing flux and then the torch flame should be played on the plates to heat them up but without producing local fusion. In other words, do not hold the flame steadily in one place long enough to cause the metal to melt. Move it back and forth until the temperature has been raised to a point somewhat above the melting temperature of the spelter. Wire spelter is very convenient for many situations and a supply should always be kept on hand. You can apply the

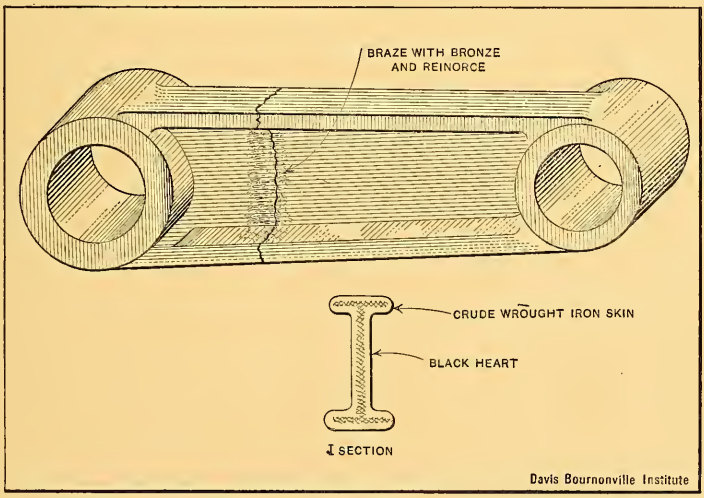

FIG. 1. BRAZING A BROKEN MALLEABLE CAST IRON LEVER.

wire spelter the same as wire solder and often you will be able to do a smooth, clean job of brazing that would be very difficult indeed, if you used the granulated spelter because of the difficulty of applying it where needed.

When the spelter flows and runs into the joint it spreads very quickly, and the job may be done before you know it, especially if the parts are closely fitted together. Little spelter will

be needed then; when it begins to flow keep watch of the under side to see when it penetrates and appears. As soon as the spelter appears to be spread through the joint turn off the torch and let the job cool under the protection of some non-conductor of heat like asbestos paper. If asbestos paper is not available, any protector at hand should be used in order to prevent severe cooling stresses being produced that might warp the parts or fracture them.

The brazing produced with the ordinary grades of spelter will do very well for uniting brass and copper but if you are going to unite steel parts by brazing and the job requires considerable strength it will be advisable to use bronze welding wire and braze at a higher heat. The joint produced by molten bronze will be very strong and it will have an advantage important sometimes that the heat required is several hundred degrees less than required for fusion welding of steel.

Broken Malleable Castings Should Be Brazed

We have spoken about the difficulty of welding broken malleable iron castings, and have advised brazing instead wherever possible. This is a case evidently for which brazing is superior to welding, because unfortunately welding requires so high a heat that the malleable iron is changed to a poor grade of cast iron, and the resulting welds is necessarily weak and faulty. On the other hand, a well brazed joint will be as strong as the original casting, or stronger. A broken malleable casting should be prepared for brazing by first thoroughly cleaning and removing all rust and foreign matter. If the parts are thick it may be advisable to bevel the edges slightly in order to confine the molten spelter and direct it into the joint. When the parts are thin no beveling is necessary but when thick and of considerable cross section area the amount of spelter required may make beveling desirable. The bevels provide troughs and prevent the undesirable spread of the brass over the surface. The beveling should be cut so as to leave "witness" or location parts untouched by which the alignment can be fixed and maintained. When the joint is filled the troughs produced by beveling should also be filled in order to make a smooth surface.

When brazing malleable iron use a bronze welding wire and bronze welding flux. The bronze wire will make a stronger bond than an ordinary spelter and in general, as has been previously stated, it should always be used in brazing parts that require high tensile strength. Use the ordinary wire spelter only for brazing parts requiring low tensile strength and which might be injured by the high fusing temperature required for the bronze wire.

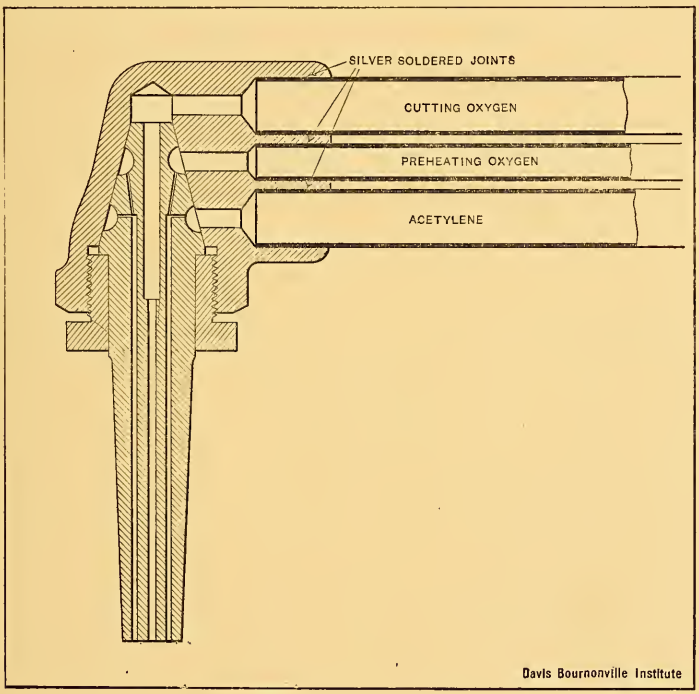

FIG. 2. SILVER SOLDERED JOINTS IN A TORCH HEAD.

Spelters or brazing metals are generally copper and zinc alloys consisting of about equal parts of copper and zinc. Spelter of this grade melts at about 1600 degrees F. The higher the copper content the higher the melting temperature. Spelter containing four parts copper and one part zinc melts at about 1850 degrees F. On the other hand, spelter containing one part copper and four parts zinc melts at 1300 degrees. The one to one alloy combines strength and a comparatively low melting temperature.

Silver Soldering

Silver solder is another strong hard solder very useful for new work and repairing. A flux should be used to protect the metal and the parts to be soldered should be clamped together with sheet silver solder between and slowly raised to a red heat with the torch at which temperature the silver will fuse and unite with the steel. A silver soldered joint is very strong when properly made and will stand repeated bending stresses, thus fitting it for band saw repairs and other work subjected to bending and shocks.

The welder who learns to braze in order that he may use it when desirable should know that the fumes rising from brass, spelter and zinc are poisonous and should not be inhaled. Brazing should not be long continued in a small closed room. Work near an open window or in a large room well ventilated when doing a heavy brazing job. Also use care in heating as the torch flame temperature is far above that required to melt brass and spelter. When you see white fumes rising reduce the heat by removing the torch flame. The zinc is burning out of the metal, weakening its structure and poisoning the air.

Questions

1. What is common spelter?
2. Why is spelter called hard solder?
3. Why is the torch more effective for brazing than a forge or furnace?
4. How should brazed joints be fitted?
5. What effect have grease and rust on brazing?
6. Which is the best for torch brazing—granulated or wire spelter?
7. Why braze malleable iron?
8. Is a brazed joint reliable?
9. What is silver solder used for?
10. What should be done about ventilation when brazing?

DAVIS-BOURNONVILLE
OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

GAS, ELECTRIC AND THERMIT WELDING

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

Form 393

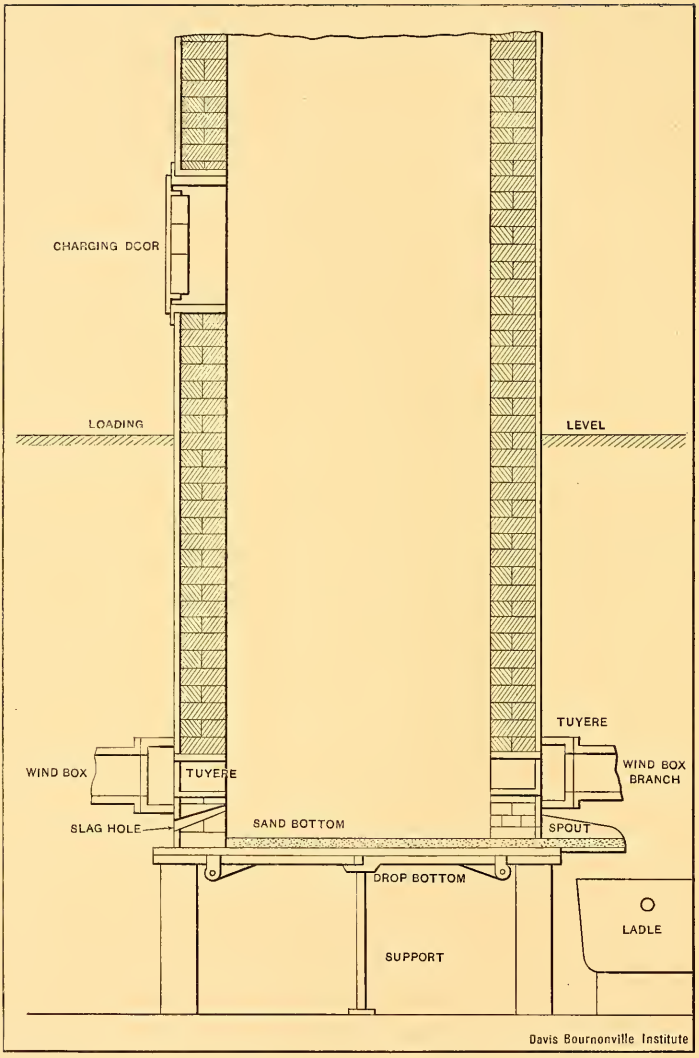

FIG. 1. THE FOUNDRY CUPOLA SOMETIMES USED FOR "BURNING ON"

GAS, ELECTRIC AND THERMIT WELDING

Oxy-Acetylene Apparatus Readily Portable and Low Priced—Electric Welding of Two General Types—Spot Welding Essentially a Manufacturing Process—Electric Arc Produces Dazzling Light—The Goldschmidt Thermit Process—Thermit a Compound of Aluminum and Iron Oxide—Preparation for Thermit Welding—Pouring the Tremit Steel—The Oxy-Acetylene Welder Should Not Undertake Impractical Jobs.

Gas, electric and thermit welding processes are comparatively new developments and in a sense they are competitive methods of uniting metals by fusion but the competition is more apparent than real because each type of welding is in general suited only to its own field. There is some overlapping of the fields, of course, but each has its own pretty clearly defined lines of work. Gas or oxy-acetylene welding is preeminently the means for doing general repair work of which there is always a great quantity and now exceptionally an enormous amount especially in the devastated regions of Europe resulting from the wreck of war. The electric welding processes are, in general suited to manufacturing chiefly and the thermit process is, a repair process for welding thick heavy metal sections.

Oxy-Acetylene Apparatus Portable and Low-Priced

The oxy-acetylene process of welding is suited to both manufacturing and repair work. It has advantages for repair work over all others. The apparatus is readily portable, comparatively low priced and may be used in almost any situation or location. It is preferred by general repair shops, garages, machine shops, field repair gangs and jobbing shops having a variety of repairing to be done under all kinds of conditions. The welds produced with the oxy-acetylene torch when manipulated by a skilled welder are considered generally superior to the welds made by the electric arc process, having greater elasticity and density. The apparatus for field use is self-contained consisting of two cylinders with their regulators and pressure gauges,

the hose and the torch only. The accessories required are few and easily transported. It is usable in remote regions where no electric current is available and the heaviest welds are within its scope. However, when it comes to very heavy welding, the question arises whether the cost may not exceed the cost of thermit welding. The oxy-acetylene welder should believe thoroughly in his process but he should recognize its limitations on heavy work and exercise judgment when asked to estimate on a heavy repair job.

Electric Welding of Two General Types

The electric welding process is of two general types—spot and arc. Both operate on the same principle, fusion being produced by the heat transformation of an electric current. When a current passes through an electric conductor the temperature rises owing to the resistance. The rise in temperature may not be perceptible in an ordinary wire or cable as a wire having comparatively large cross section is a good conductor. The current flowing meets with insufficient resistance to raise the temperature much about that of the surrounding atmosphere. But if the quantity (amperage) of electricity flowing through a wire is suddenly raised say ten or twenty times the normal and the wire would quickly get hot and perhaps fuse with a blinding flash and loud report. This is what happens when a fuse blows. The fuse is a safety device made of metal of low fusing temperature, and is so proportioned that it breaks down before the conductor itself is greatly overloaded.

Electrical heat is proportional to the electrical resistance; if the conductor offers high resistance to the passage of current it becomes hot and finally reaches the fusing temperature if current of sufficient strength is long supplied. Fusion produced by electric heat is thus the basis of electric welding. The heat results from a series of transformations. It is first produced generally by the burning of coal under steam boilers in a power house. The burning coal generates steam which drives the engines or turbines which, in turn, drive the electric generator. The electric current produced is transmitted by wire to the welding machine where meeting with excessive resistance

the energy reappears in the form of heat, producing fusion and welding. In oxy-acetylene welding, the heat required for fusing is produced by combustion of acetylene in an atmosphere of oxygen.

Spot Welding Essentially a Manufacturiug Process

Spot electric welding is essentially a manufacturing method of uniting thin overlapping metal parts. Spot welds are made in spots by two opposite copper electrodes which are pressed against opposite sides of the sheets to be welded with considerable force and held for a few seconds while the current flows from one electrode to the other through the metal. Fusion is produced in a small spot and the two sheets are almost instantly welded by the pressure of the electrodes which forces the fused metal between them intimately together. Spot welds are strong and are well suited for many kinds of sheet metal products not requiring water-tight seams. They are used, sometimes for the fabrication of pressure containers also which afterwards are brazed or soldered in the seam to make them liquid or gas-tight.

The electric spot welding process is advantageous for uniting galvanized or tinned sheets as it is not considered good practice to gas weld galvanized iron or tin. When fused under the torch zinc and tin unite with the steel and produce a weak metallic structure. If you are ever required to gas weld galvanized metal with the torch be careful to clean all the zinc or tin off mechanically or with acids before fusing the metal. The same precaution should be taken with tin sheets. A welded tin sheet will be so brittle if welded without removing the tin that it may break apart with a slight blow.

Electric Arc Produces Dazzling Light

When a strong electric current flows from one metallic conductor to another it tends to persist when the conductors are separated. The current jumps through the air, producing great heat and dazzling light. The heat is so intense that metal electrodes are molten almost instantly. The electric arc welding process is based on this principle and is capable of wide

application. It is a strong competitor of gas welding in manufacturing, shipbuilding, car building and fabricating plants. But it has some disadvantages which must be frankly recognized. In the first place, arc welds are not generally as strong as those produced by the oxy-acetylene torch. The welds are more brittle and porous. Arc welds, therefore, are not suitable for pressure containers made of thin metal because the joint is likely to be brittle and full of small holes. The porosity of arc welds varies with the electrodes used, but whether much or little it is likely to give trouble when the containers are made to transport gasoline and other volatile liquids. The porosity will, under some conditions, give trouble also in thick welds subjected to high heat and pressure. Superheated high pressure steam will escape through a porous electric weld of considerable thickness.

The second important disadvantage of the electric arc process is the intensly dazzling light produced which is very dangerous to the eyes if unprotected by colored glasses. The light is not only dangerous to the welder himself but to other workmen nearby who may, in an unguarded moment, look directly at it. A short exposure of the eyes unguarded by colored glasses close to the electric arc may result in partial or total blindness. This, from the standpoint of the workman is a most serious drawback to the use of the electric arc in manufacturing and fabricating plants. The welder must never work without protecting the eyes and even with the best eye protectors some welders suffer from eye troubles. The ultra violet rays also penetrate thin clothing and often burn the flesh on the body producing the same effect as sunburn.

Two Methods of Electric Arc Welding

There are two general methods of using the electric arc for welding. In one the metal is fused with a carbon electrode and adding material is fed to the joint the same as with the oxy-acetylene process. In the other process a metallic electrode is held in an insulated holder and the current fuses the electrode itself and deposits the metal in the joint as it drops from the end. This method has the advantage of employing only one hand but as the welder generally holds a screen of colored glass

before the eyes with the other hand, both hands are employed. When welding with metallic electrodes the end of bare electrodes must be held at a certain distance from the work. If the distance is too short a short circuit results and if too great 60 to 110 for wrapped electrodes. With alternating current and bare electrodes an open circuit voltage of 125 to 150 volts is the arc is broken. Considerable manipulative skill is required, therefore, to weld successfully with bare electrodes. The common diameter of the bare electrodes is $\frac{5}{32}$ inch, and the current values range from 75 to 250 amperes, depending on

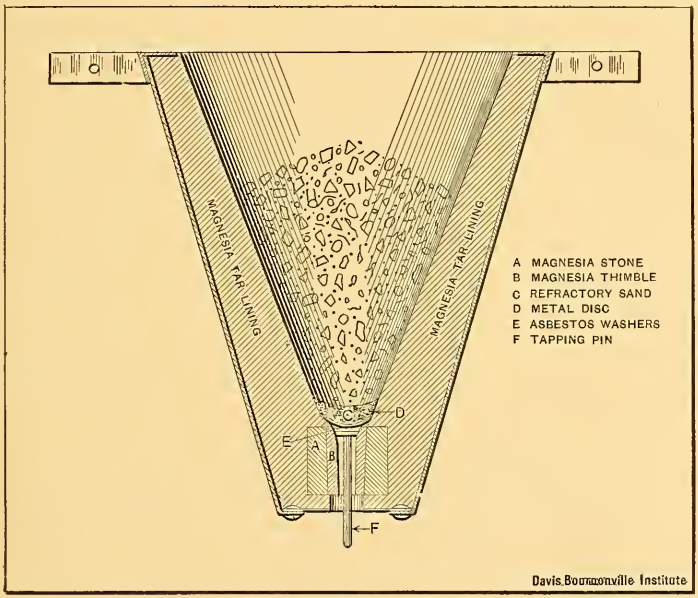

FIG. 2. SPECIAL CRUCIBLE FOR THE REACTION AND POURING OF THERMIT STEEL

the thickness of the plates. From 150 to 200 amperes are generally used with the $\frac{5}{32}$ inch electrode. The open circuit voltage for direct current should be between 35 and 110 volts. For bare and coated electrodes 35 to 75 volts are required, and necessary with resistance control, and 110 volts with reactance control. If an internally regulated transformer is used open circuit voltage under 110 volts produces an arc that can be

readily controlled. Whatever the current used the regulation should be such that the current will not increase over 50 per cent when the electrode touches the work and the arc is thus short-circuited.

From the foregoing you will realize that the electric arc process requires special apparatus and considerable technical knowledge on the part of the one in charge, as well as skill on the part of the operator.

The Goldschmidt Thermit Process

The third important modern method of welding is the thermit process developed some years ago in Germany by Goldschmidt. It is one of the interesting developments of chemistry in which finely powdered aluminum plays an important part with iron oxide. It is essentially a casting process analogous to "burning on" in a foundry, requiring a mould into which the molten steel is poured around the broken parts to unite them. The thermit process is eminently suited for making heavy repairs and is generally used for welding broken rudder posts, stern frames, locomotive frames, engine crankshafts, propeller shafts, heavy castings and in general, work having large cross sections. The time and labor required to prepare for thermit welding is considerable. But the actual pouring of the molten metal which forms the weld requires but a few seconds.

Thermit Composition of Aluminum and Iron Oxide

The molten steel results from the chemical reaction of thermit, which is the name given to a mixture of finely divided or powdered aluminum and iron oxide. Aluminum, as you know, has a strong attraction for oxygen and unites with it rapidly when raised to the fusing temperature. The reason that aluminum does not rust like iron is that the thin oxide coating on the surface protects the metal beneath and prevents the oxidizing action from progressing. Iron oxide, however, does not protect the metal beneath and so the rusting process continues indefinitely until the metal is completely oxidized. The aluminum in the thermit mixture robs the iron oxide of its oxygen when the reaction has once been started by heat and produces aluminum

oxide and molten steel. The reaction takes place with such rapidity and intensity that a temperature of about 5,400 degrees E. is produced. So intense is the heat that it is sufficient to melt about 15 per cent of its weight in mild steel punchings which are used to increase the amount of molten steel and to reduce the temperature. The reaction in the crucible takes place in a few seconds when started and the metal is immediately poured into the molds. The practice of using thermit for making welds is briefly as follows:

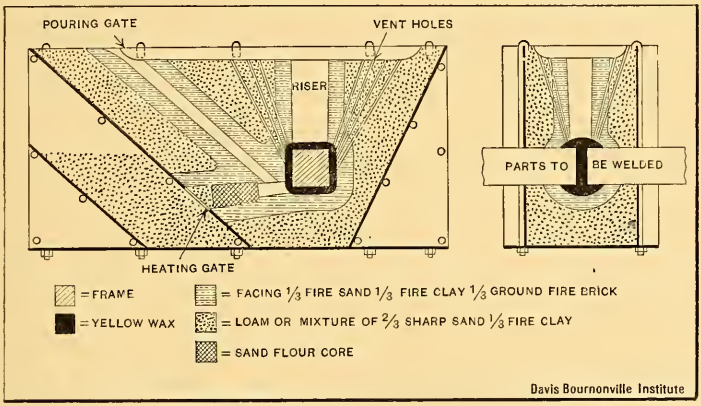
POURING GATE
VENT HOLES
RISER
PARTS TO BE WELDED
HEATING GATE
= FRAME
= YELLOW WAX
= FACING 1/3 FIRE SAND 1/3 FIRE CLAY 1/3 GROUND FIRE BRICK
= LOAM OR MIXTURE OF 2/3 SHARP SAND 1/3 FIRE CLAY
= SAND FLOUR CORE
Davis Bournonville Institute

FIG. 3. MOULD FORMED AROUND THE PARTS TO BE WELDED

Preparation for Thermit Welding

The broken parts to be welded must be lined up the same as for oxy-acetylene welding in order that when welded the restored part should be of the same shape and dimension as before. Sufficient metal must be cut away from the joint to permit the molten steel to enter between the ends in sufficient quantity to produce fusion and complete union when cold. The thickness that must be cut away depends on the size of the parts ranging from, say one-half inch up to one or two inches, or even more on very heavy sections.

The parts must be thoroughly cleaned to remove all grease, scale and rust. When the parts have been prepared the space between them is packed with yellow wax and a reinforcing band of wax is molded around the parts thus giving the effect of a

reinforcing collar. Wooden patterns for risers and pouring gates are provided, and a sheet metal box is made for a mold. The patterns of the risers and gates are assembled in contact with the wax in their proper locations and then a mold of fire sand, fire clay and powdered fire brick is made about them, using the sheet iron box to hold the mold in place. When the molding has been completed the riser and gate patterns are removed and the mold and parts to be welded are heated with oil blow-torches to dry out the mold, melt the wax and preheat the metal. Provision is made for drawing off the wax as it melts. When the wax has been melted out a cavity is left in the mold into which the molten thermit steel is poured. The parts are preheated in order to prevent chilling of the thermit metal.

The Reaction in the Crucible

The mold is now ready for pouring. A special crucible having an outlet at the bottom is set up over the mold and the amount of thermit and steel punchings required for the weld, with some excess, is charged into the crucible. The outlet in the bottom of the crucible is sealed with a sort of tappet valve the stem of which projects beneath. A refractory protective washer is provided above the valve to prevent premature fusion and discharge of the contents. The chemical reaction in the thermit charge is started by firing a fuse which produces a sufficiently high temperature to start the reaction of the aluminum and iron oxide. When once begun the reaction spreads rapidly and requires only about 30 seconds during which time the aluminum unites with the oxygen of the iron oxide producing aluminum oxide and thermit steel having a temperature of 5,400 degrees F. As stated, a quantity of mild steel punchings is mixed with the thermit to increase the quantity of steel and to reduce the temperature of the welding metal.

Pouring Thermit Steel

As soon as the reaction is completed, the crucible is tapped by raising the valve at the bottom and the molten metal flows into the mold at so high a temperature that it fuses the preheated metal parts and unites them perfectly when cooled with

a steel casting. The band of wax formed around the parts when preparing the mold is reproduced in a collar of reinforcing steel around the weld. Of course, this collar must be dispensed with if the break should happen to be in a part that must be machined to its original dimension. The spectacular appearance of the reaction in the crucible and the remarkable results so quickly obtained make thermit welding one of the most interesting methods of repairing broken parts. But, as stated in the foregoing, it is in general suited only for heavy repair work in which field it is preeminent. The oxy-acetylene welder should not regard the thermit process as a serious competitor in a general way as it should be used only for the heavy welding that is impractical of repair by other processes.

The Oxy-Acetylene Welder should not Undertake Impractical Jobs

This brings up an important matter in oxy-acetylene welding practice. The welder must learn to estimate the cost of welding and to judge if the job offered is one that he can handle to the satisfaction of the customer. It is not to his interest to undertake to weld with the torch repair jobs that could be better handled by thermit welding, neither should he undertake to gas weld small parts in large quantities that can be electrically welded at lower cost. This does not mean, however, that gas welding cannot compete with electric welding in manufacturing, if the proper appliances are provided and the work systematized on a manufacturing basis. It does mean that the jobbing welder should not undertake to do manufacturing on a jobbing basis.

We have given you in this review of the three modern processes of manufacturing a general idea of their scope and limitations as we believe it is desirable that you know something about all of them. You can more clearly realize the limitations of your own field as well as its possibilities. The oxy-acetylene welder should be enthusiastic but practical. He should not be carried off his feet and undertake impracticable jobs. A failure is a poor advertisement and a customer will remember a failure much longer than many satisfactory performances.

Questions

1. What is electric spot welding suited to?
2. Is spot welding a repair process?
3. What are the two principal types of arc welding?
4. What precaution must be taken in all arc welding in regard to the eyes?
5. Is arc welding essentially a repair process?
6. What advantages do you see in the oxy-acetylene process?
7. What is required to weld a field job with the oxy-acetylene torch?
8. What is the thermit process of welding?
9. For what is the thermit process best suited?
10. Would you undertake to weld a 10-inch broken shaft with the torch? Why?
11. What process would you recommend?
12. What should you do when welding galvanized steel with the torch?

DAVIS-BOURNONVILLE
OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

GAS PIPES AND MANIFOLDS

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

Form 394

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GAS PIPES AND MANIFOLDS

Oxygen Piping—Welded Pipe Lines—Size of Pipe Required for Oxygen Line—Safety Valves for Oxygen Lines—Acetylene Pipe Lines—Gas Manifolds—Pressure Regulators—Branch Line Pressure Regulators—Copper Must not be used in Acetylene Lines—Backfire Chamber or Water Seal for Acetylene Lines—Generated Acetylene Supply—Piping Gases to Welding Benches.

The ordinary gas requirements of the individual welder are provided for by drawing from one cylinder of acetylene and one cylinder of oxygen at a time. The limitation on the use of gas from cylinders applies only to acetylene, the rule being that no more than one-seventh of the capacity of an acetylene cylinder be used hourly in order to avoid drawing over the acetone. But not all gas welding requirements will be properly provided for in this manner. You may sometimes have to weld a big job on which three or four torches will be working at once which means that you will be consuming three or four times as much gas as usual. Moreover, in welding shop practice you must provide for the use of torches at several stations, and that means large gas consumption, and piping for the gases to convey them throughout the plant to the stations. Piping for gas used in oxy-acetylene welding and cutting might be considered to be merely an ordinary steam pipe fitting job. But the conditions that must be complied with require considerable special knowledge, not possessed by the regular steam fitter.

Oxygen Piping

We will first speak of oxygen pipe line installations. Ordinary black iron gas pipes screwed together without clear oil or grease on the threads may be used for oxygen pipe lines with general satisfaction. Soap or a graphite compound should be used on all screwed connections of apparatus containing oxygen as the use of clear oil alone is considered dangerous because of the possibility of some oil remaining inside the pipe and taking fire in the oxygen atmosphere. If this should happen the fire

might continue to burn after the oil was consumed by feeding on the iron until it became so thin that the walls would burst under the pressure. Graphite mixed with tallow, or the graphite compound gredag are allowable lubricants for screw threads but they should be used sparingly, and pains should be taken to prevent any excess getting inside the pipe or couplings. Aquadag contains no oil or grease, being a colloidal water and graphite compound in which the graphite is permanently suspended in the water. This may be used with entire safety and without being over-particular about any excess getting inside the pipe.

The precaution should always be taken when erecting an oxygen pipe line to blow out each pipe thoroughly, rapping it with a hammer to dislodge scale and foreign substances. When the line is connected it is also highly desirable to blow it out with compressed air under considerable pressure if possible. Leave nothing in the oxygen pipe or manifold of a combustible nature whatsoever. A piece of pine wood may take fire, and if fire is once started you never know what may happen.

Welded Pipe Lines

Permanent installations may be welded with very satisfactory results. A welded line will last indefinitely and having no screwed joints except at the valves and other connections there is little liklihood of leaks developing to cause trouble at a critical time. Welding is feasible only with iron or uncoated steel pipe. It is not advisable to weld galvanized pipe as the welding can be accomplished only with difficulty, and the joints are likely to be brittle. When iron or steel coated with zinc are fused the zinc is likely to amalgamate with the metal and injure its physical characteristic.

Size of Pipe Required for Oxygen Line

The pipe diameter required for an oxygen line depends of course on the length of the line and the number of stations to be provided for. A ¾-inch pipe will supply all the oxygen needed at twenty ordinary stations provided the length of the line does not exceed 250 to 300 lineal feet and the total hourly consumption does not exceed 500 cubic feet. A steam fitter perhaps will

recommend a larger pipe than ¾-inch for the volume of gas to be supplied and would be correct if the line were being erected for compressed air used for power purposes. It is necessary then to provide a sufficient pipe diameter to prevent considerable drop in pressure. But oxygen is a somewhat difficult gas to manage and it is advisable to use no larger diameter pipe than experience has demonstrated to be sufficient. The comparatively small

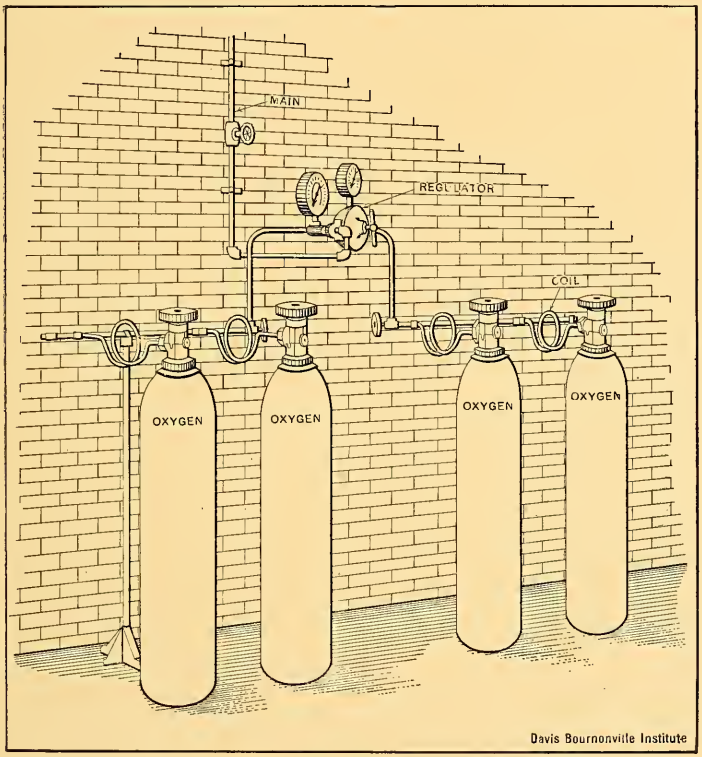

FIG. 1. MANIFOLD AND CONNECTIONS FOR FOUR OXYGEN CYLINDERS

pipe recommended will carry all the oxygen required for twenty stations and will give less trouble probably than a larger pipe. You see that the situation is quite different than with compressed air. A compressed air pipe should provide for as little drop in pressure as possible but considerable drop in pressure of the oxygen supply is of little importance because the source is under

very high pressure, if furnished in cylinders; an apparatus has to be provided to reduce the pressure so that it can be used in the torch. The function of a pressure regulator is to reduce pressure that is much too high for welding and cutting and to maintain an even pressure in the torch. Hence, a comparatively small pipe may be safely used to supply a fair sized welding installation. The drops to the welding tables should be ½-inch pipe.

The usual means should be provided for supporting an oxygen pipe line, and it should be run where it will be out of the way and not likely to be struck by heavy objects. Clamps or hangers should be provided at regular intervals to support it. If the pipe is welded use bent sections for the ells in preference to the commercial ells for two reasons, the first being to avoid the use of screwed joints and the second being to avoid the disturbing effect of a sharp right angle turn on the flow of gas. It is essential in a pipe distributing system that the flow be always constant and as free from waves as possible. A small pipe of uniform diameter is therefore preferable to a larger pipe of uneven diameter and containing many right angle turns.

Safety Valves for Oxygen Lines

A simple and reliable safety device should be provided in an oxygen pipe line to relieve over pressure in case the pressure regulator leaks or fails to function properly. An effective device consists of a thin brass disc clamped between a flange and a cap. The flange is tapped for screw connection to the pipe line and the cap is perforated with several holes communicating to the atmosphere. The diameter and thickness of the metal disc is such that it bursts under a pressure of say 100 pounds per square inch and relieves the excess pressure, thus calling attention to the defective regulator.

Acetylene Pipe Lines

It is necessary to use a somewhat larger pipe for the acetylene supply than for the oxygen because the acetylene pressure should never exceed 15 pounds in the pipe lines. A 1-inch pipe

should furnish all the acetylene required for twenty ordinary welding stations and hence a ¾-inch oxygen pipe and a 1-inch acetylene pipe would be considered to be in about the proper ratio for most plant installations that provide gases for hand torches only. Gas welding machines, however, may require much larger pipe lines, depending on the nature of the installation and the number of machines, of course. A circular slide rule is furnished by the Davis-Bournonville Co. for calculating the sizes of pipe lines for any installation.

Gas Manifolds

When the gases are furnished in considerable volume from cylinders it is usually necessary to provide a manifold for each pipe line with pressure reducers to step down the cylinder pressure before it is admitted to the mains. In a loosely managed plant a pressure regulator may be required on each acetylene cylinder to control the gas escaping to the manifold. The reason for this is that the cylinders containing different pressures are allowed to be connected to the same manifold. One cylinder may contain acetylene under a pressure of say 200 pounds per square inch and the one next to it a pressure of only 100 pounds. If separate regulators are not provided the result is that the cylinder containing gas under 200 pounds pressure discharges abnormally fast while the one containing the gas under 100 pounds pressure, discharges not at all until the pressure is down to 100 pounds. The effect is bad, of course, the object for which more than one cylinder is provided being defeated by such practice.

The need of a pressure regulator for each acetylene cylinder connected to the manifold is eliminated simply by connecting cylinders only to the manifold which contain practically equal pressures. If four cylinders each containing acetylene under 225 pounds pressure are connected to the manifold the discharge from each should be approximately one-fourth of the total amount of gas used hourly or daily. When one cylinder has discharged to the lowest pressure permissible to use in the line all of the four should also be discharged, and all must be disconnected and replaced by another battery of four. If this practice is faithfully

followed no trouble need be apprehended from acetone being drawn over from one cylinder because of too rapid discharge. In order that the discharge of gas should be the same in all of a battery of acetylene cylinders it is necessary, however, that all should be working under the same conditions. It will not do for one cylinder to be set close to a steam radiator in winter as its temperature will rise thereby and the rate of discharge will exceed that of the others in the cooler zone. Provide as nearly as possible the same conditions for all of a battery connected to a manifold.

A manifold is simply a special pipe or header provided with as many nipple connections as are required to unite the cylinders and the pipe line. Flexible coil pipes should be provided for the connections between the manifold and the cylinders. The oxygen manifold should be made amply strong to withstand a pressure of 2,000 pounds to the square inch. The internal bore or diameter should be kept to the smallest dimension consistent with free flow of gas. A half-inch hole through the manifold will be ample for a battery of four or six cylinders. If made of a casting it is advisable to use bronze and to make sure that it is free of porous spots and pinholes. In some cases stop valves are provided at each nipple connection so that the cylinders may be changed one by one without interrupting the flow of gas. If it is necessary to maintain an uninterrupted supply of gases, the use of stop valves, of course, is necessary but it is practice to be condemned in general because of the danger of some of the valves being left closed and all the gas being drawn from one cylinder alone. This is not of especial moment in the case of the oxygen supply but is a serious matter with the acetylene supply. The preferable practice in the case of acetylene supply is to provide two manifolds connected to the pipe line and to provide no stop valves between the manifold and the respective cylinders. This permits a battery of cylinders to be kept in reserve ready for instant use, and the discharged cylinders may be removed and replaced at leisure. There will never be any question about the opening of the stop valves. This practice also permits a line regulator to be removed and replaced without interruption of service.

Pressure Regulators

A pressure reducer or regulator must be installed between the manifold and the pipe line. It is not allowable to carry the high pressure oxygen in the pipe lines and depend on the station regulators to reduce the pressure to the working pressure required. Oxygen under a pressure of 1,800 to 2,000 pounds per square inch would be much more difficult to keep within bounds than if reduced to a line pressure of say 50 pounds. Much better regulation will be obtained also by providing a master regulator at the manifold and then the drop in pressure to be provided for by the individual regulators will be comparatively low.

Free acetylene compressed to 225 pounds in a pipe line is highly dangerous, and is under no circumstances permissible. The manifold for the acetylene should be of as few cubic inches capacity as possible so as to limit the volume of free gas under high pressure as much as practicable. The line pressure to be maintained by the master regulator should not exceed 15 pounds per square inch.

Branch Line Pressure Regulators

If the installation is extensive there being several branch lines tapped into the distributing main it may be advisable to provide pressure regulators at each branch, especially in oxygen pipe lines. Long pipe lines present difficulty in pressure regulation there being a tendency for surges or waves to be set in motion which seriously affect torch operation. Regulators on branch lines will dampen out waves and make the problem of individual torch regulation comparatively easy.

Copper Must Not be Used in Acetylene Lines

While it is not likely that copper tubing would ever be suggested for an acetylene pipe line it is, nevertheless, advisable to point out the danger of such an installation. Acetylene in contact with copper forms copper acetylide which is potentially dangerous, being likely to explode, rupture the pipe and cause a fire. The use of brass in acetylene lines should also be discouraged but brass stop valves and other fittings are permissible. Gal-

vanized iron pipe with screw joints or black iron pipe welded or screwed together may be used.

In erecting pipe lines for oxygen and acetylene do not be too sparing of stop valves. They should be provided at each manifold between the line regulator and the line so that the regulator may be removed and replaced without discharging the contents of the line. If the lines are long, stop valves should be provided in the mains near each group of welding stations in order to save time in case a pipe is ruptured and immediate stoppage of gas flow becomes imperative. Stop valves should also be placed in the drops to the welding tables in order that the regulators may be removed and replaced without interrupting the service. A few dollars invested in stop valves at the various welding stations may save much trouble and inconvenience in a busy time.

Backfire Chamber or Water Seal for Acetylene Lines

The acetylene line must be protected from the propagation of backfires by a backfire chamber of approved design. An effective device is one in which the gas bubbles through water in passing. The water seals the passage to a backfire and stops its propagation. Care must be taken to keep the water replenished as the effectiveness depends on the water entirely. Backfire chambers should be provided near all junctions of branch lines so that each line will have its own protection.

Generated Acetylene Supply

So far we have spoken only of the use of acetylene compressed in cylinders dissolved in acetone. The acetylene supply of a manufacturing plant, however, should in general be furnished by an acetylene generator or a battery of generators. The manufacturer using considerable gas can generate his own acetylene much cheaper than he can buy it dissolved in cylinders. There will be less likelihood of service interruption because of cylinders not arriving on time and the trouble of sending empty cylinders back to the supply station will be avoided. Calcium carbide may be purchased in large lots in sealed metal containers which preserve it indefinitely. Water only is required to convert

the carbide into acetylene. The cost of maintenance is small and the labor charge is inconsiderable.

The generator house should be located in a remote section of the plant away from boilers, furnaces and railway tracks. A pit must be provided for discharging the slaked lime residuum. It is not generally allowable to discharge the lime into the city sewers as it is likely to settle to the bottom and stop them up. As the generator house may be a long distance away from the welding station it may be necessary then to provide a larger acetylene supply line than recommended in the foregoing.

Piping Gases to Welding Benches

A word in regard to the method of piping the gases to the welding benches is in order. The pipes may be carried overhead and the supply lines dropped to the benches. This form of installation is quick and cheap to put in but it has the disadvantage of being unsightly and in some cases it is very objectionable. The overhead pipes shut out daylight and tend to make the interior of the welding shop unnecessarily gloomy. The gas supply pipes should, when feasible, be laid on the floor along the wall or under the benches and led up to the welding stations from below. There is then nothing in the way above the welding bench to interfere with the welder and his work. The pressure regulators should be placed where they can be seen without effort and controlled without stopping work.

Questions

1. Is the use of iron pipe allowable for oxygen pipe lines? Why?
2. What lubricants would you use on the screw threads of an oxygen pipe line?
3. Which would you prefer, a welded pipe line or a screwed joint line?
4. What size oxygen pipe would you use for supplying gas to twenty ordinary welding stations, 300 feet from the manifold?
5. What is the purpose of a manifold?

6. How would you connect an oxygen cylinder to a manifold?
7. Would you use a pressure reducer between each oxygen cylinder and the manifold? Why?
8. Would you put a pressure regulator between the manifold and pipe line? Why?
9. Would you put a pressure regulator between the main and branch lines? Why?
10. Why would you provide a pressure regulator at each station?
11. What kind of pipe would you use for an acetylene line?
12. What size acetylene line would you provide for 20 or 25 welding stations 300 feet from the generator?
13. Would you use copper tubing in any part of an acetylene generator?
14. Would you use brass globe valves in an acetylene line?
15. Would you use petcocks to drain water from an acetylene line? Why?
16. What is the maximum pressure to be expected in an acetylene line?
17. How would you connect a number of acetylene cylinders to a manifold?
18. Would you use pressure reducers for each cylinder? Why?
19. What is the function of a safety valve in an oxygen line?
20. Is a safety valve needed in an acetylene line?
21. If a safety valve is not needed what safety device should be provided?

DAVIS-BOURNONVILLE
OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

THE CUTTING TORCH AND ITS USE

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

Form 395

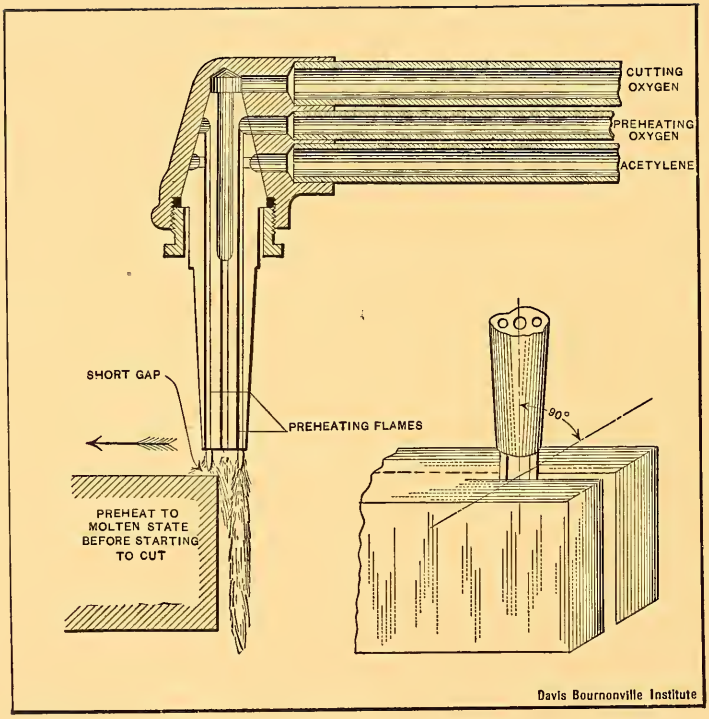

FIG. 1. THE CUTTING TORCH STARTING A CUT, AND IN ACTION.

THE CUTTING TORCH AND ITS USE

Historical—Iron and Steel are Fuels—Burning Steel Produces High Temperature—Metals Cut with the Torch—The Modern Cutting Torch—Cutting Tips and Gas Pressures—Nicking Billets—The Cutting Torch a General Utility Tool.

Early in this course of lectures your attention was called to the fact that steel will burn in an atmosphere of oxygen. A steel or iron wire supported in a jar of oxygen will take fire and burn with a shower of sparks when a corner is heated white hot. It burns fiercely and is quickly consumed. The products of combustion are various iron oxides. Steel in an oxygen atmosphere will not burn until some part is raised to the igniting temperature. The same law holds that applies to ordinary combustion. You cannot burn wood without first striking fire with a match and igniting the wood or raising a portion to the temperature at which it unites with the oxygen in the air. When that has been accomplished, combustion continues until the fuel has been consumed. The same applies to the steel burning in the oxygen. When once combustion has been started the heat produced by the burning steel maintains an igniting temperature and combustion proceeds until all the steel is consumed.

An atmosphere of oxygen can be produced locally by directing a jet of oxygen where required. Hence, it is possible to produce an oxygen atmosphere in contact with steel or iron with a jet issuing from a torch tip and to start combustion or burning with a preheating flame. The zone of combustion will be confined to the oxygen atmosphere, and that can be fixed by the size and direction of the jet.

Historical

The possibility of cutting steel and wrought iron with the oxy-acetylene torch was discovered in the early years of its development and was recognized as being one of the very valuable characteristics of the gas torch. There is no more striking and amazing demonstration than the cutting of a steel plate with the stream of oxygen issuing from the torch tip. The jet of oxygen

cuts a narrow, clean kerf like a saw, and the direction of the cut can be controlled with such nicety that discs, dies, templets and complicated forms may be produced in steel that afterwards require little machining in order to make them perfectly true to form.

Although the chemical effect of oxygen on hot metals was well known early in the nineteenth century, the first known reference to the use of oxygen for cutting or piercing metal was made in 1888 in a paper read by Thomas Fletcher before the Society of Chemical Industry in Liverpool, England, in which such experiments were discovered as "fusing of a hole through a chilled iron plate such as those used in burglar-proof safes". Fletcher was interested in the manufacture of apparatus using illuminating gas and perhaps had the use of illuminating gas in conjunction with oxygen in mind.

A German patent was given to Herman A. E. Menne in May, 1901, on the use of oxygen for cutting, or as it was termed in the patent, "melting"—particularly melting out tap holes in blast furnaces which had become solid through cooling.

A paper read by Chevalier de Schwarz before the meeting of the Iron and Steel Institute, in May, 1906, called the attention of engineers to the new method of cutting iron and steel with oxygen as follows:

"All experienced blast furnace engineers are acquainted with the great trouble caused by tap-holes of blast furnaces becoming closed with solid iron so that they cannot be opened up by ordinary appliances without considerable loss of time. The usual means employed for opening a closed top-hole is a steel bar driven by hand rammers, or if these do not suffice, a heavy ram suspended on chains and worked by a dozen men is employed. It sometimes happens that the steel bar snaps off leaving the end in the hole already made and making matters worse than they were before. Coke and heated blast as well as petroleum have been employed for opening closed tap-holes or tuyeres and also powerful electric currents, but none of these work quickly enough and besides are too expensive.

"The application of compressed oxygen has worked very quickly and has besides the merit of being cheap. The iron to

be pierced is first heated at the spots selected for making the hole by means of an oxy-hydrogen flame. The oxygen and hydrogen are compressed in separate steel flasks, each flask being provided with a suitable outlet valve. The burner consists of an outer and inner tube, the outer tube supplying the hydrogen and

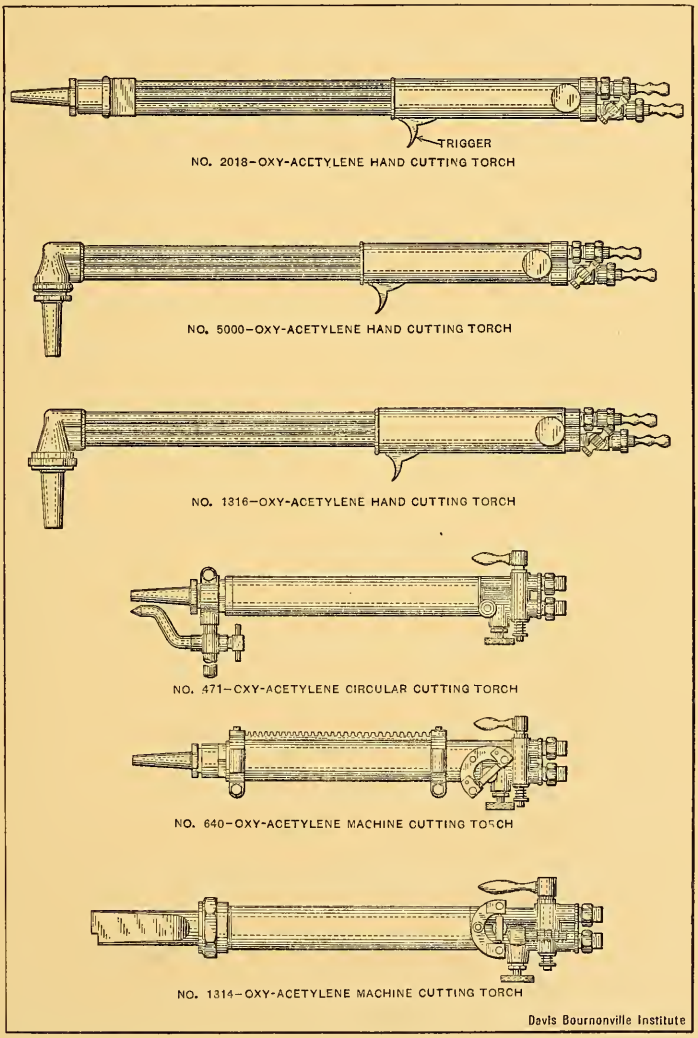
TRIGGER
NO. 2018–OXY-ACETYLENE HAND CUTTING TORCH
NO. 5000–OXY-ACETYLENE HAND CUTTING TORCH
NO. 1316–OXY-ACETYLENE HAND CUTTING TORCH
NO. 471–OXY-ACETYLENE CIRCULAR CUTTING TORCH
NO. 640–OXY-ACETYLENE MACHINE CUTTING TORCH
NO. 1314–OXY-ACETYLENE MACHINE CUTTING TORCH
Davis Bournonville Institute

FIG. 2. STYLES OF DAVIS-BOURNONVILLE CUTTING TORCHES.

the inner one the oxygen. The hydrogen is turned on first after which the oxygen. The pressure of both gases is first kept low but is gradually raised and regulated in such a way as to give a very hot flame which heats the spot on which it impinges to a white heat. The pressure of the oxygen is then increased to such an extent that the iron commences to burn, which is shown by sparks being thrown out. Thereupon the oxygen pressure is increased to 450 pounds per square inch while the supply of hydrogen is entirely shut off. It is now that the iron burns, replacing the hydrogen as a combustible, whereupon a degree of heat is developed which far surpasses that produced by the oxy-hydrogen flame. The high pressure of the escaping oxygen at the same time serves to force out all the molten iron thus keeping the hole burned through perfectly clean throughout the operation. This explains why it is possible to perforate a solid block of cold iron or steel say 16 inches thick. Moreover, this extraordinary feat can be performed in from one to two minutes."

The author then proceeded to give an explanation of the great increase of heat due to the use of pure oxygen which is of interest as it clearly illuminates the extraordinary performance of the cutting torch and gives the reader a notion of the power of condensed fuel. His words are as follows: "Burning one pound of hydrogen with oxygen produces 62,000 B. T. U. while burning one pound of iron with oxygen produces 2,968 B. T. U., but at atmospheric pressure one pound of hydrogen occupies over 80,000 times as much space as one pound of iron. Therefore, a certain volume of iron when burned with oxygen produces 4,000 times as much heat as an equal volume of hydrogen in the same space. In other words, when iron burns in oxygen, the heat is concentrated on a very small area. This explains the enormously high temperature produced and the quick action notwithstanding that at the same time the temperature of the compressed oxygen is low because of its compression and subsequent expansion."

In September, 1906, a United States patent was issued upon an application filed in August, 1905, to Felix Jottrand, a Belgian, on the process stated to cover a method of cutting plate, pipe and other metal articles with a device using a mixture of oxygen

and hydrogen or other combustible gas together with a jet of pure oxygen. There is no direct evidence of the date when oxygen was first used for cutting in the United States. The claim is made that one Harris of Cleveland cut pieces of steel by this method in 1904. Cutting became associated with the inception of the oxy-acetylene welding process and the early welding torches were furnished with a cutting attachment that could be clipped to the side of the torch. The oxygen was drawn from a separate hose and regulator which required a separate cylinder or a double connection to attach two regulators to one cylinder thus making a clumsy arrangement. This apparatus was more of an interesting curiosity than a practical working tool. Upon the development of the cutting torch with only two hose connections, the use of the cutting process advanced rapidly, its development being made possible by the development of commercial methods of producing oxygen cheaply and its extensive distribution throughout the country compressed in cylinders.

Metals Cut with the Torch

The only metals that can be cut with facility with the gas cutting torch are wrought iron, mild steels and steels of comparatively low carbon content. High carbon steels are successfully cut with the oxygen jet if preheated to a temperature that depends somewhat on the carbon content and the various alloys contained. The higher the carbon content the greater the degree of preheating. A black heat will suffice if ordinary tool steel, whereas a low red may be required for some of the alloy tool steels. Cast iron cutting is in process of development. True cutting of cast iron has not yet reached the commercial stage but the progress made within the past year indicates that gray cast iron may eventually be cut with as smooth and narrow a kerf perhaps as mild steel. At the present time cast iron cutting is a combination of cutting and melting. Part of the metal is blown away as slag but the greater part is molten iron. Obviously the process cannot be thermally efficient until the iron itself burns completely and thus contributes the heat required for its own combustion. Brass and bronze plates have been cut by interposing them between steel sheets. The cut produced in the steel

sheet persists through the brass or bronze plate and the lower steel sheet confines the kerf to approximately the same width as that in the steel sheet on top.

The Modern Cutting Torch

The modern gas cutting torch is similar in appearance to the welding torch but differs in the construction and method of control. The Davis-Bournonville cutting torch comprises three metal gas tubes united in the head and a trigger controlled oxygen valve. Two of the gas tubes are for oxygen and the third is for acetylene, hydrogen or other combustible gas. The gases required for the preheating flame mix in the head of the interchangeable tip the same as in the welding torch. The torch is applied for cutting by adjusting the needle valves to produce a slightly oxidizing flame. The preheating flame applied to the edge of a steel plate quickly raises it to the white hot temperature when the trigger controlled oxygen valve is opened thus admitting streamers or jets of pure oxygen alongside of the preheating flame. Instantly the white hot metal takes fire and burns with a shower of sparks. The burning (oxidizing) metal rolls down the sides of the kerf igniting and burning the metal in its path and falling on the floor below.

The rate of cutting varies with the thickness of the steel, the size of tip and oxygen pressure. The No. 1 interchangeable tip in the Davis-Bournonville torch requires an acetylene pressure of three pounds per square inch and an oxygen pressure of ten to twenty pounds depending on the thickness of the metal. This size tip is suited for cutting steel $\frac{1}{8}$ to $\frac{5}{16}$ inch thick. The gas consumption, if continuous cutting is about 12 cubic feet of acetylene and 55 cubic feet of oxygen per hour on $\frac{5}{16}$ inch steel. At the other end of the scale but by no means at the limit of heavy cutting, is the No. 5 tip, suited for cutting 10 inch steel and using 30 cubic feet of acetylene, and 1,000 cubic feet of oxygen hourly. The pressure of oxygen required for heavy cutting ranges from 100 to 150 pounds per square inch. High oxygen pressures are used for very heavy cutting. With high pressure the thickness of cutting possible is truly amazing. Armor plate 24 inches thick, and even thicker, has been cut successfully with the oxy-hydrogen torch.

Uses for Gas Cutting

Sufficient has been said to indicate that the uses to which the hand operated and machine operated cutting torch can be put to in manufacturing, shipbuilding, car building, boiler making, fabricating and repair work are legend. One of the important uses of gas cutting is in the humble junk yard. Old steel boilers can be cut with the torch into junk and merchantable plate at small cost. For fabrication the cutting torch is invaluable as steel beams, angles, channels and other structural shapes may be cut and trimmed to any angle required with the torch at a fraction of the expense of cutting mechanically. The process is especially

Acetylene and Oxygen Pressures

DAVIS-BOURNONVILLE STYLE C CUTTING TORCHES
with Style 12 Tips

Tip No.	Thickness of Metal Inches	Acetylene Pressure Lbs.	Oxygen Pressure Lbs.	Acetylene* Consumption Per Hour	Oxygen* Consumption Per Hour
1	1/8	3	10	12.2 cu. ft.	42 cu. ft.
1	3/16	3	15	12.2 "	48 "
1	1/4	3	20	12.2 "	55 "
1	5/16	3	20	12.2 "	55 "
2	1/4	3	10	12.2 "	62 "
2	1/2	3	20	12.2 "	84 "
2	3/4	3	30	12.2 "	106 "
2	1	3	35	12.2 "	116 "
3	1	4	30	19.7 "	142 "
3	1 1/2	4	40	19.7 "	172 "
3	2	4	50	19.7 "	202 "
3	3	4	60	19.7 "	232 "
4	3	5	60	30.6 "	316 "
4	4	5	70	30.6 "	356 "
4	5	5	85	30.6 "	416 "
4	6	5	100	30.6 "	476 "
5	6	6	90	30.6 "	600 "
5	7	6	100	30.6 "	668 "
5	8	6	125	30.6 "	838 "
5	10	8	150	30.6 "	1,008 "

Operators frequently adjust the pressure regulators from one to two pounds above the figures given in the table to allow for gauge variations and drop of pressure when the gases are supplied in cylinders.

* Gas consumption per hour is the maximum with torch burning continuously.

valuable in the field where ordinary cutting machines are not available.

This brings up the question of power required for mechanical cutting. Steel generally is a high tensile strength metal and can be cut apart with tools only by the expenditure of considerable power and by the use of expensive cutting tools. The tensile strength ranges from 45,000 up to 250,000 pounds per square inch, and the power required to separate it by ordinary cutting tools is roughly proportional to the tensile strength. It makes no difference with the cutting torch, however, provided the carbon content is not excessive. The oxygen flame cuts indifferently thin and thick metal, treated and untreated without expensive and time consuming clamping devices.

Billet Nicking

One of the numerous economies effected by the use of the cutting torch was developed during the war for cutting bars and billets for shells. Such enormous quantities were required to be cut to shell lengths that it was impossible to get the machines and the operators required for machine cutting. The cutting torch was used for nicking billets with great success. It was found that a billet 5½ inches thick, for example, required nicking with the torch flame to a depth only of ½ to ¾ inch. The cut cooled by pouring cold water into the kerf immediately started a crack which made the breaking of the billet under a drop hammer, hydraulic press or on a bulldozer a comparatively easy and quick operation. For cutting 3-inch bars, for instance, some manufacturers of shells provided nicking tables or beds on which several bars 8 or 10 feet long were laid at once and guide strips at right angles were provided at regular intervals for guiding the nicking torch. The operator nicked the billets by passing the torch across the table with the tip held against the guide strip. The flame nicked the bars beneath to a depth determined by the rate of torch movement. The nick extends to a nearly uniform depth through a range of about 120 degrees.

The nicked bars were broken apart on a bulldozer at the rate of about 80 to 100 strokes a minute.

Some manufacturers of shells adopted other methods among which of interest was that of dropping the nicked billets a con-

siderable distance and letting the shock complete the rupture. Three or four billets were raised to a height of 35 or 40 feet by means of a lifting magnet and allowed to fall on steel bars set so that the nicked billets would strike at or near the nicked pieces. As a matter of fact, however, it was found that the shock would break a nicked billet in three or four places simultaneously if it struck just right. The production of shell length pieces by this method, of course, was very rapid and of low cost.

The Cutting Torch General Utility-Tool

The gas welder should use the cutting torch as a tool for preparing work for welding wherever it will save time and labor. Of course, its use is practically limited to wrought iron and steel. But for beveling steel, cutting angles and preparing structural parts for assembling and welding, the cutting torch has no equal as an efficient tool. Steel plates that require trimming or shaping may be cut very quickly and smoothly with the torch. If manholes are required it is not necessary even to drill a hole as the jet will penetrate and when penetration has been accomplished the cutting may be directed at will. It is usual to apply the jet for penetrating a plate inside the line to be cut out as the penetrating jet does not cut as cleanly as it does after penetration has been produced. Thus, in cutting out a manhole you should lay out the shape and location accurately marking it with chalk and then start the cut by penetration inside the line a short distance and as soon as the flame has penetrated, work to the line and then follow the line closely.

Questions

1. Why is it possible to cut wrought iron and steel with the torch?
2. What must be done first in order to start a cut?
3. What happens if the metal becomes cold?
4. What gases are used for cutting?
5. What is the purpose of the trigger-controlled valve in the cutting torch?
6. What metals can be cut with the torch?
7. Is it possible to cut cast iron?

8. What pressure of acetylene should be used for cutting a steel plate ¾ inch thick?

9. To what working pressure of oxygen should the regulator be set when starting to cut 6-inch steel?

10. How should the operator hold a cutting torch when cutting an arc.

11. For what purposes is the cutting torch useful? Name four.

12. What should be done after using the cutting torch for beveling a steel plate for welding?

13. What is billet nicking?

14. Why is it possible to easily break a nicked steel bar?

15. What should be done by a torch operator before starting to cut up an old boiler for junk?

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OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

GAS CUTTING MACHINES

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

Form 396

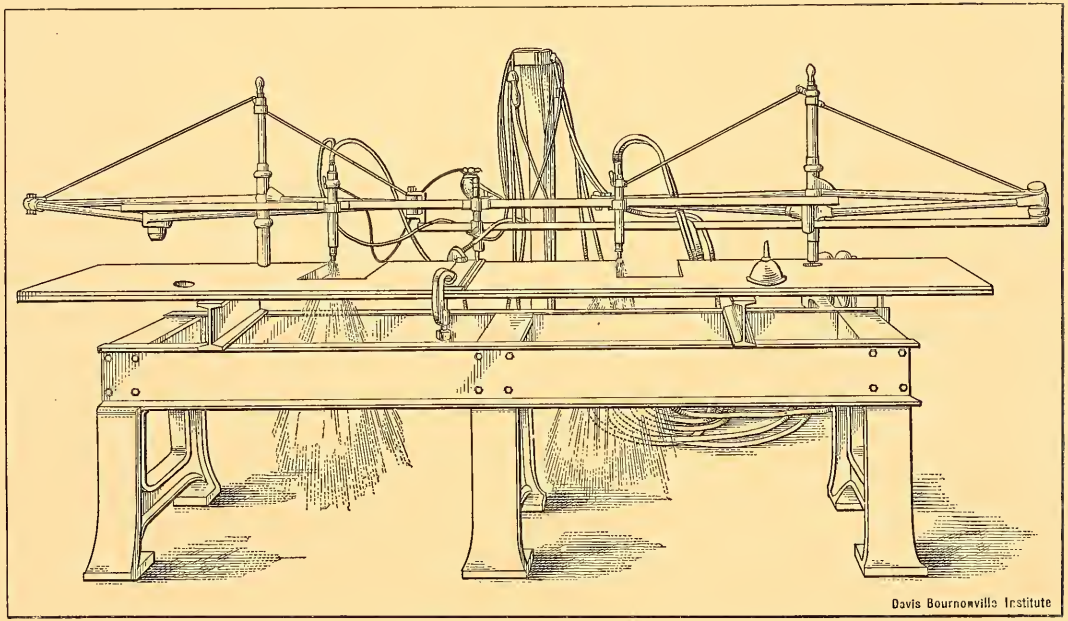

FIG. 1. NO. 2 OXYGRAPH CUTTING STACK OF STEEL PLATES WITH TWO TORCHES

GAS CUTTING MACHINES

Limitations of Hand Cutting—Mechanical Traverse Required as well as Mechanical Support—Water Cooling Not Required—Path of the Torch Flame—Davis-Bournonville Gas Cutting Machines—The Oxygraph—Layout for Cutting a Steel Die—The Radiagraph—The Pyrograph—The Holograph, Camograph and Magnetograph—Comparison with Machine Tools.

To cut iron and steel smoothly and accurately with a gas cutting torch requires considerable manipulative skill, especially when the metal is thick. The hand torch operator must hold the torch steadily but not firmly, and must follow a line straight or curved, as the case may require. The torch movement must keep in step with the rate of cutting, progressing no faster or slower. If the torch lags behind the cutting action it stops, and if the torch moves forward too rapidly the burning away of the metal will not keep pace, and the metal will cool so that again the cutting action is interrupted.

Mechanical Traverse Required as well as Mechanical Support

It is important then that any size of tip for cutting a given thickness of steel should be traversed at a certain rate; the rate will depend on the pressures of the gases supplied. When the gas pressures have been adjusted the effective rate of cutting is fixed. The operator must approximate this rate very closely in order to prevent interruptions of the work. A machine cutting torch, therefore, requires not only a support for the torch which will guide and direct its movement but also mechanical traverse or feed that can be varied to suit the thickness of the metal, the size of tip and other conditions that govern the rate of cutting. No cutting torch machine is complete without variable mechanical traverse, but for small circles and similar cutting hand traverse by means of worm gear works very well.

The Davis-Bournonville Company has developed a number of successful gas cutting machines, and a distinguishing feature

of the larger and most successful machines is mechanical traverse, the rate of which may be changed at the operator's will.

Machine cutting, the same as machine welding is done with special torches having the tips in line with the body instead of being set at various angles as is necessary in the line of hand welding and cutting torches. It is not necessary to provide water cooling for cutting torches as the heat affecting the torch is not nearly as great as with the welding torch, and moreover, the volume of oxygen passing through the cutting torch is so large that its cooling effect is considerable.

Path of the Torch Flame

The path of the cutting torch through steel is comparable to the cut made by a metal saw working under heavy feed. The sides are rough but regular, nevertheless, within limits. Comparatively little machining is required to finish a flame-cut steel block smooth and true. The sides are cut approximately at right angles with the top or bottom surfaces. Steel die blocks cut to approximate shape with the mechanically-guided and mechanically-traversed torch are in condition for finishing to size with two or three light machine cuts. The heavy work is done by the torch, leaving the accurate finishing work to be done on toolroom machines which are better suited for finishing than for "hogging" work. The flame can be held close to the line when cutting out with confidence that the cut out die will finish up smooth and true. The metal is not injured by the flame to an appreciable depth, the oxidizing influence being confined mostly to the metal cut away. The oxide remaining on the parts is very thin and all is removed by the light finishing cuts.

Davis-Bournonville Gas Cutting Machines

Machines developed for cutting wrought iron and steel by the Davis-Bournonville Company are called the Oxygraph, the Radiagraph, the Pyrograph, the Camograph, the Holograph and the Magnetograph. Some of these machines are special in their characteristics and suited only to special purposes but others are more or less universal of application and are, therefore, applicable to machine shop and tool room uses and for manufacturing and jobbing purposes.

The Oxygraph

The Oxygraph is a machine of the pantagraph type, the torch being supported on a pantagraph frame that provides for horizontal movement in all directions to cover a plane within its scope. The pantagraph frame of the No. 1 machine is supported at one corner of the frame, and on the opposite end is a table on which a drawing may be laid for tracing. The torch is mounted on the pantagraph so that the movement is reduced to half scale at the torch. Hence, a drawing to be reproduced by a cut out pattern in steel with a torch must be drawn two times the required size. The lines of the drawing

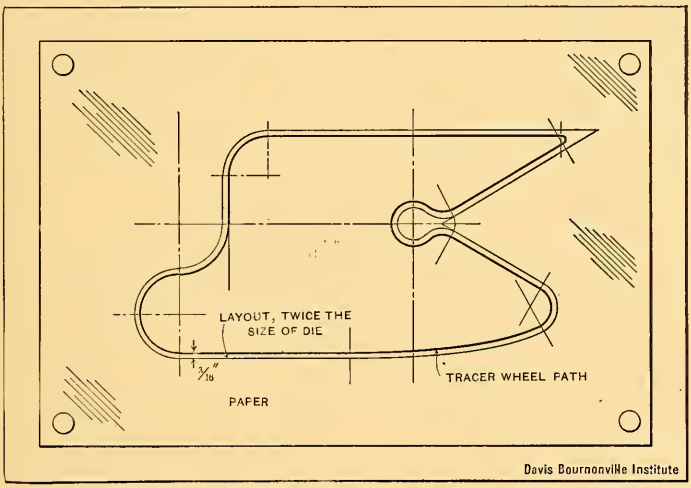

FIG. 2. PATTERN DRAWN ON PAPER TWO TIMES SIZE, AND TRACER WHEEL PATH FOR OXYGRAPH CUTTING

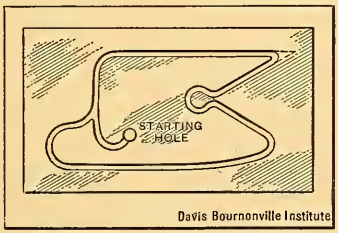

FIG. 3. PATH CUT BY THE OXYGRAPH TORCH IN A DIE BLOCK FOLLOWING PATTERN

provide allowance for the kerf and finish. These lines are are paralleled with lines drawn at such a distance away as will mechanically traversed by a motor-driven tracing attachment, the speed of which can be varied to suit the thickness of the metal.

Machine steel plates of any thickness up to 10 inches or more may be cut with the oxygraph to any required shape. The torch follows straight lines, curves, sharp or obtuse angles, and in fact any form that can be laid down on paper and practically cut from a steel plate.

The Oxygraph is made in two sizes, the small size being suitable for machine shop and toolroom use while the large size machine, which has a double pantagraph frame and two cutting torches for making double cuts simultaneously, is essentially a manufacturing proposition. Drawings laid out for cutting on the Oxygraph require the path of the tracer wheel to

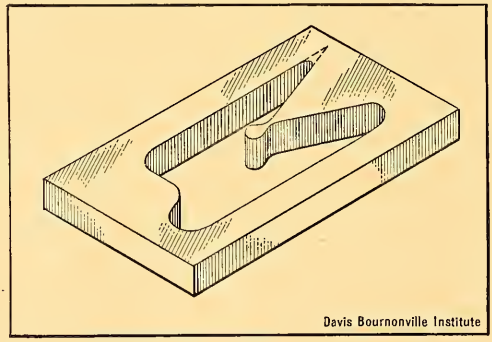

FIG. 4 DIE CUT ON OXYGRAPH, USING PATTERN SHOWN IN FIG 2

be included in order that the torch path will coincide in reduced scale to the path shaped on the drawing. The tracing wheel path should be drawn $\frac{3}{16}$ inch outside of the shape outline when a punch or similar part is to be cut from a steel block, but if a die is to be cut then the path for the tracer wheel should be shown by lines $\frac{3}{16}$ inch inside the shape outline.

Layout for Cutting a Steel Die

Fig 2 shows the pattern or drawing for cutting the steel die shown in Fig. 4. The outer line is the shape of the required opening in the die, and the inner outline is the path of the tracer wheel. Fig. 3 shows the die block in reduced scale,

the ratio being one to two. The torch starts cutting through a hole in the center and the path is then directed to the drawn line with the tracer wheel following the path inside.

As stated in the foregoing, the large size Oxygraph has a double pantagraph frame, and is fitted with two cutting torches for making two cuts simultaneously. The position of the torches

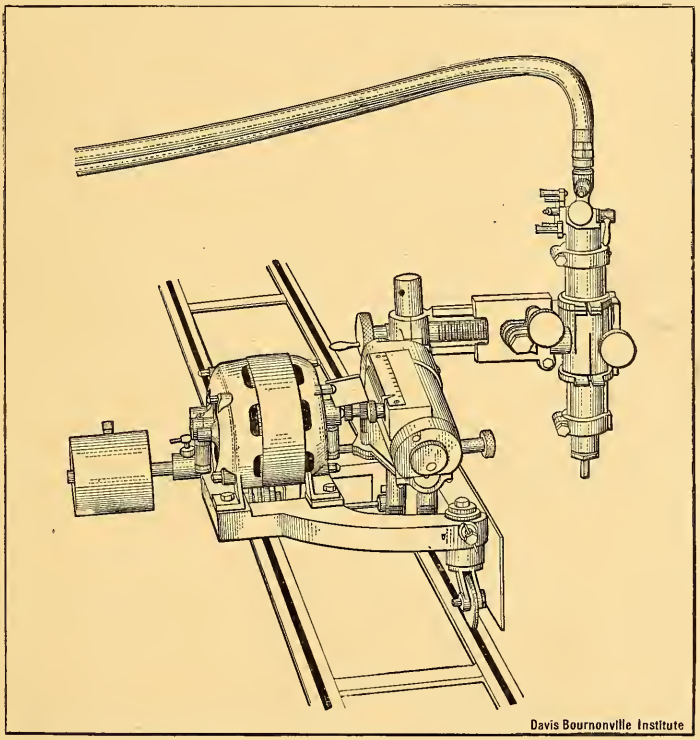

FIG. 5. RADIAGRAPH FOR STRAIGHT AND CIRCULAR CUTTING

and the tracing wheel are adjustable. This machine is suitable for cutting several steel parts simultaneously, and is useful where many duplicate parts must be cut from mild steel plates. For example, take the plate frames of an electric mine locomotive, requiring two openings to be cut away for the pedestal jaws in which the driving boxes are fitted. The No. 2 Oxygraph is admirably suited for work of this character. When put in the care of men who have some skill and training, it is capable of a

large production. The number of parts that can be cut simultaneously depends, of course, on the thickness and the torch equipment provided, for example, 12 to 16 plates, ¾ inch thick can be readily cut with accuracy when stacked one upon the other.

The Radiagraph

The Radiagraph is a motor-driven machine provided with a cutting torch and is intended for cutting straight lines or circles in steel plates of any thickness up to 18 or 20 inches. The speeds of cutting vary from 2 to 10 inches per minute, according to the thickness of the plate, size of tip and the oxygen pressures provided. The Radiagraph operates upon a track for straight line cutting. The track is made of parallel rails of whatever length required to compass the work. Circular cutting is accomplished by the use of a radius arm of adjustable length, the torch being carried at the outer end. The carriage is supported on three wheels, and is driven by a variable speed electric motor which may be used with either direct or alternating current on either 110- or 220-volt circuits. The complete machine weighs about fifty pounds and thus is readily portable. It is adapted for a wide range of use in shipyards, steel mills, forge shops, structural steel plants, fabricating plants, junk yards, etc.

The Pyrograph

The Pyrograph is a special gas cutting machine designed especially for use in boiler shops for trimming flanged boiler heads, flue sheets and similar boiler parts. But it is adaptable to many other uses in the fabrication of steel parts. The machine is similar in general outline to a wall or post radial drill. A radial arm supports the torch carriage which is provided with a motor for driving the tracing mechanism or friction rollers. The torch is adjustable for bevel cutting and the mechanical speed fixed according to the thickness of the plate being trimmed, insures cutting a smooth true bevel. A flanged boiler head, firebox or flue sheet may be accurately trimmed with the machine in a fraction of the time required by other methods. The flue sheet to be trimmed is blocked up level beneath the swinging arm with the flange to be beveled, upward. The cut is started at the

required height with the assurance that the flange will be trimmed to the height required, and that the cut will be maintained throughout. The automatic feed provides means for following irregular outlines without the guidance of the operator thus leaving him free to attend solely to the torch. The machine has a cutting area covering a circle of 9 feet diameter at one setting and as the traverse on the arm is 10 feet the machine can cover a semicircle of 20 feet in diameter when mounted on a column. The pivot support, of course, can be arranged so that the torch may be applied to any part of a circle 20 feet diameter.

The Holograph, Camograph and Magnetograph

The Holograph is a simple hand-operated machine cutting torch for cutting holes in the web of steel rails or steel struc-

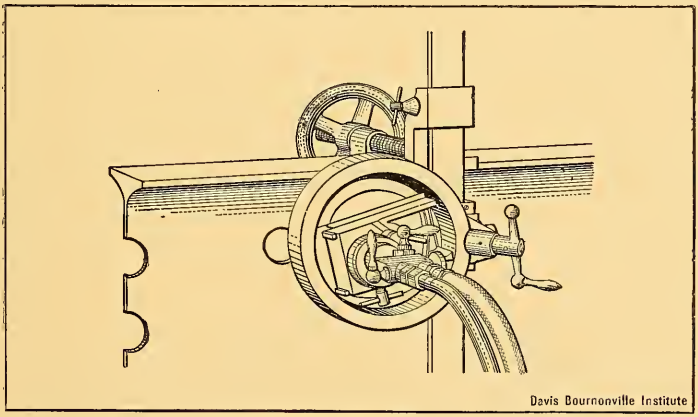

FIG. 6. HOLOGRAPH FOR CUTTING HOLES IN STEEL RAILS AND STRUCTURAL SHAPES

tural parts of not more than ¾ inch thickness. It is so designed that the rotating part carrying the torch can be quickly clamped in position on the I-beam, channel or rail at the required height and position. The torch flame pierces the web without previous drilling and smooth, round holes from 1 to 2 inch diameter will be cut in from 30 to 60 seconds. The advantages of a device of this type for fabricating shops field work, railway and

bridge work and many purposes required by workers on steel structures, tanks and other engineering work are obvious.

The Camograph is an adaptation of the Holograph having the same general form and construction with the addition of a cam and mechanism for guiding the torch flame in other than circular paths. It was primarily designed for cutting slotted holes in street railway rails for the bolts required to hold the fish-plates. The precise shape of the hole cut is controlled by the shape of the cam provided. Hence, the machine requires special cams for each distinct operation.

The Magnetograph is a radius cutting machine held against the parts to be operated on by three electromagnets. The torch is mounted on an arm that may be slowly rotated by means of a handwheel operating through a worm and wormwheel. The machine was designed especially for cutting holes in armor plate, ship plate and for all similar purposes where no easy means of clamping other than magnets are readily available. It cuts circles up to 12 inches diameter and steel plate from ¼ inch up to several inches thickness may be quickly cut with true edges. Cutting is accomplished at varying speeds, depending on the thickness of plates, the rate varying from 3 inches up to 20 inches per minute or even faster on thin plates. The holding device, consisting of three electromagnets is operated by connecting to any direct-current electric circuit of the required voltage.

Comparison with Machine Tools

The construction and operation of mechanically-guided cutting torches is an interesting study for anyone concerned with the performance and production in metal working. The machine torch operates on a principle so widely different from that of the ordinary machine tool that it is somewhat difficult for the engineer familiar only with conventional types to appreciate the wonderful possibilities of directed combustion of steel. The strength of steel is so great that all ordinary machine tools require very strong, rigid frames, broad slides, well supported cutting tools and powerful drives. The speeds of operation are limited by the endurance of the cutting tools and the power

that can be applied. The cutting torch, however, requires practically no power for traversing it, and the supporting members needs only sufficient strength and rigidity to guide the torch accurately in its path. The power required to cut the steel is supplied by the steel itself through its own combustion.

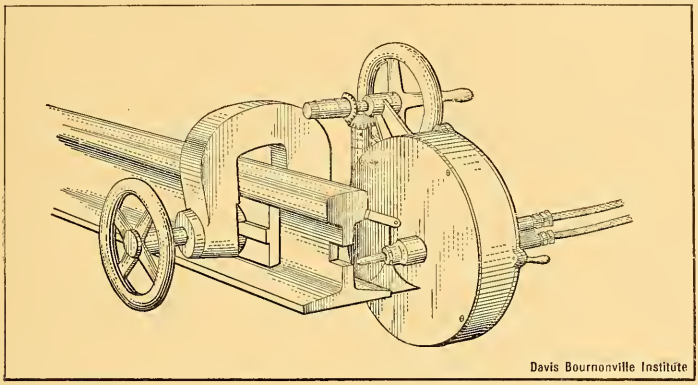

FIG. 7. CAMOGRAPH FOR CUTTING SLOTTED HOLES IN STEEL RAILS

It makes no difference whether the steel has an ultimate tensile strength of 50,000 pounds per square inch or 200,000 pounds provided the carbon content is not too high. The oxygen jets cuts it away smoothly and rapidly.

Questions

1. Do you understand the principle of the machine cutting torch and the hand cutting torch to be the same?
2. What distinguishes the machine cutting torch from the hand cutting torch?
3. Why is a mechanical support desirable for a cutting torch?
4. Why is it possible with a machine cutting torch to cut a greater thickness than is possible with a hand torch?
5. What is the principle of the oxygraph cutting machine?
6. What is first necessary when undertaking to cut a die of tool steel with the oxygraph?
7. Is it necessary to drill a hole through steel when starting to cut a manhole? Why?

8. What is the Pyrograph cutting machine used for chiefly?
9. What is the chief expense in cutting with either the hand torch or the machine torch?
10. For what purpose is the Radiagraph cutting machine used?

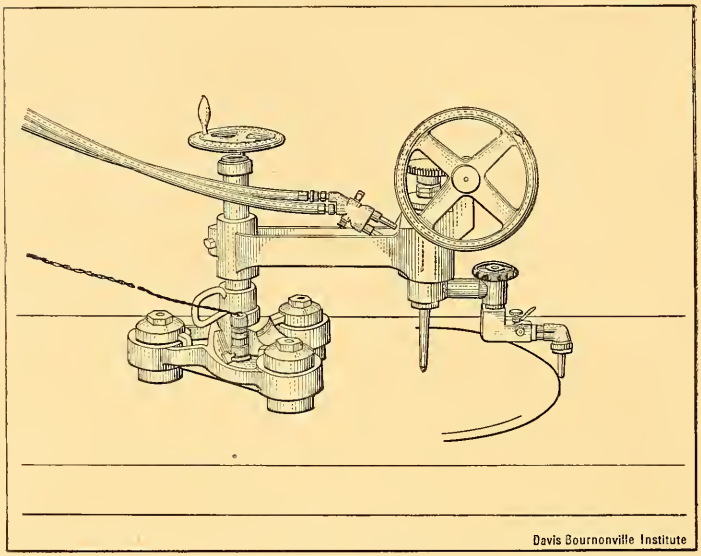

FIG. 8. MAGNETOGRAPH FOR CUTTING HOLES IN SHIP PLATES AND ARMOR. HELD IN POSITION BY MAGNETIC ATTRACTION

11. Why is a mechanical traverse important feature of the torch cutting machine?
12. Should the speed of mechanical traverse be fixed or variable?

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OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

Lecture

CARE OF THE EYES— SAFETY CONSIDERATIONS

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

Form 393

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CARE OF THE EYES— SAFETY CONSIDERATIONS

Protective Colored Glasses—Spectacles and Goggles—General Safety Considerations—Don'ts for Welders and Cutters.

Certain dangers and hazards are inherent in almost every trade and industry, and oxy-acetylene welding and cutting are not exceptions. Gases under pressure are required one of which is combustible and explosive when mixed with air or oxygen in certain proportions. When gases are furnished compressed in cylinders the welder has to deal with heavy pressures of sufficient intensity to injure his apparatus if not carefully handled. The breaking down of a regulator may burst the hose and cause injury or a fire. The torch flame is injurious to the eyes unless they are protected with suitable colored spectacles or goggles, and eye protection must not be neglected when welding or cutting.

Protective Colored Glasses

Approved colored glass spectacles or goggles must be worn by welders, cutters and their helpers if they would protect their

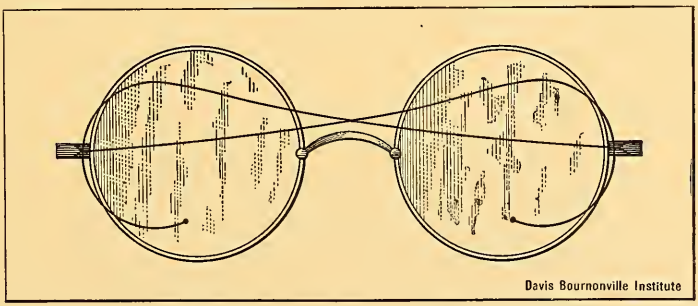

FIG. 1. SPECTACLES WITH COLORED GLASSES, SUITABLE FOR LIGHT WELDING AND CUTTING.

eyes from dangerous heat and light rays. The torch flame produces light rays of great intensity and also heat rays which may be equally destructive to the tissues of the eye. Hardly any

two men require the same eye protection. But the general rule is to provide glasses that shut off no more of the light rays than are necessary as the welder may be seriously handicapped by being unable to see what he is doing if very dark colored glasses are used. There are several tests of the suitability of colored glasses, one of which to use a pair of glasses a few

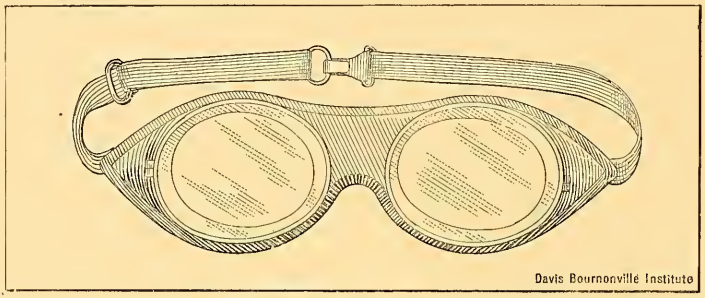

FIG. 2. LIGHT GOGGLES HAVING COLLAPSIBLE EYE CUPS, HANDY TO USE AND CARRY.

minutes while welding and then remove them and note whether white spots dance before the vision. If they are noticeable the glasses do not afford sufficient protection and darker ones should be provided. Another rough test of the suitability of spectacles or goggles is to look through them at vivid red on a blue background. Red crayon marks on a blueprint may be tried. If the markings may be plainly seen without dazzling effect the glasses

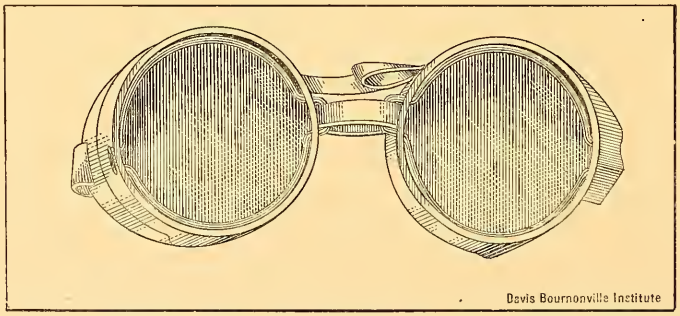

FIG. 3. VULCANIZED FIBER FRAME GOGGLES, NOT AFFECTED BY HEAT OR STERILIZING SOLUTIONS

may be used. This test, however, is not at all scientific and should be used only for want of something better.

Spectacles and Goggles

Colored glasses mounted in steel or aluminum spectacle frames as shown in Fig. 1, are suitable for light welding and light cutting. They are cheap, convenient and light. Because of the open space between the glass and the eyes, sweat is not so troublesome as with goggles or other eye protectors that prevent free circulation of air. However, spectacles should be worn only when there is little danger of flying metal striking the face. Spectacles do not afford sufficient protection from flying particles in heavy welding and should be worn only for protecting the eyes from light and heat. When there are other dan-

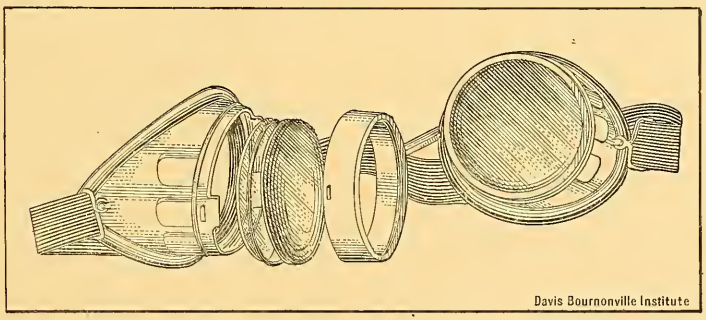

FIG. 4. GOGGLES WITH QUICKLY DETACHABLE LENSES AND CLEAR GLASS COVERS.

gers to the eyes, goggles or face masks must be worn if the welder would be safe.

Goggles are made in a variety of forms, and the choice of goggle is largely a matter of individual preference and the amount that one would be likely to invest. The goggles shown in Fig. 2 are light and the lenses are easily replaced in case of breakage. The mask is of unlined leather and an elastic head band is provided. The eye cups being collapsible the goggle can be carried in the vest pocket without a case. Cases, however, should be provided to protect the glasses from dust and abrasion. The goggles shown in Fig. 3 have frames of vulcanized fiber, light

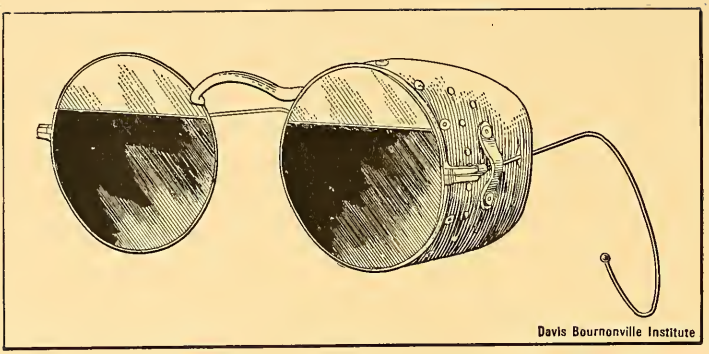

FIG. 5. BICOLOR GOGGLES, USEFUL FOR GENERAL REPAIR WELDING.

in weight and a good non-conductor of heat. The fiber is non-inflammable and infusible, and is not affected by moisture. Consequently, the goggles can be sterilized without injury, which is an important consideration where several welders are employed and the goggles are common property. The eye cups are connected with a rubber covered chain. An elastic head band is provided to hold the goggles in place. The colored lenses are protected by clear glass lenses which may be readily replaced when pitted by flying globules of molten metal. This is an important consideration when purchasing goggles. Unless the colored glass is protected it will soon be so pitted in use as to become useless

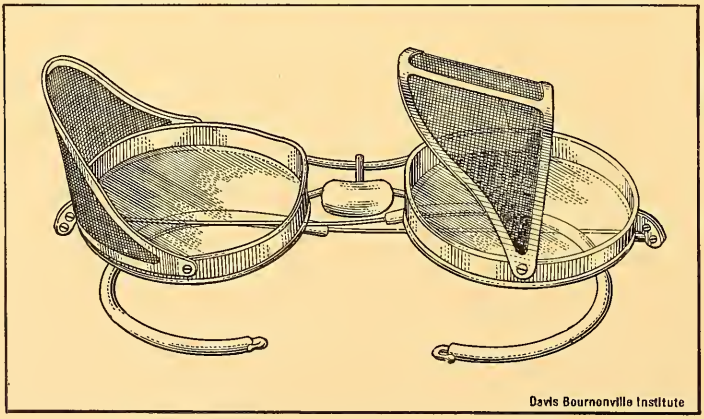

FIG. 6. SPECTACLES WITH VENTILATED SIDE SHIELDS.

It is cheaper to replace the clear glass protectors than the more expensive colored lens.

The eye cups of the goggles shown in Fig. 4 are made of aluminum, bound at the edges to prevent contact with the face. The distance between the lenses may be changed by twisting the connecting chain. The colored lenses are protected by clear cover glasses which may be readily replaced when injured by pitting. No tools are required to replace a lens, all that is required being to twist the rim slightly to one side and remove the lens by pressure with a finger applied from the inside of the eye cup.

The bi-color goggles shown in Fig. 5 are provided for welders who wish to inspect their work without the trouble of removing

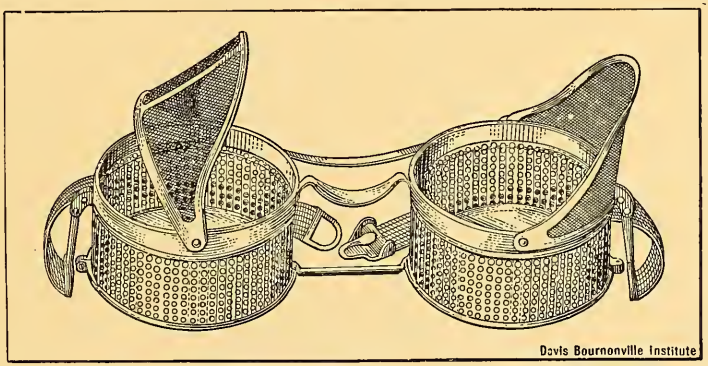

FIG. 7. GOGGLES WITH VENTILATED EYE CUPS AND SIDE SHIELDS.

colored glasses from the eyes. The lower part being colored glass and the upper part clear glass, the operator may see "daylight" through his goggles without removing them. The eye cups are flexible, ventilated leather, and spectacle bows are used instead of an elastic head band.

Spectacles with ventilated side shields and metal frames are shown in Fig. 6 and goggles with ventilated eye cups and ventilated side shields in Fig. 7. These forms are recommended for oxy-acetylene welders by the Bureau of Standards but, as stated in the foregoing, the choice of goggles is largely a matter of individual preference. A protective goggle may be everything that could be desired from the protective standpoint but if it induces excessive perspiration or is heavy and inconvenient it will

be hard to induce men to wear them. A case in point is the face mask shown in Fig. 8 which undoubtedly is effective protection. It has the advantage that the mask may be quickly raised from the eyes to permit the welder to inspect the work but the head band is more or less uncomfortable and the mask is likely to induce profuse sweating. Some men, however, find this type of eye protection agreeable and satisfactory.

General Safety Considerations

Welders and cutters should wear suitable clothing. A long apron over street clothes or overalls free from holes or rags are generally satisfactory. Attention should be given to the shoes

FIG. 8. FACE MASK MOUNTED ON HEAD BAND SO THAT IT CAN BE MADE OPERATIVE OR INOPERATIVE WITHOUT REMOVING.

as broken shoes are dangerous on account of the possibility of drops of molten metal falling into the holes and seriously burning the feet. Gloves should be worn to protect the hands from the heat of the torch flame, but avoid cheap cotton gloves that catch fire. Wear leather gloves or fabric gloves that have been treated to make them fireproof.

Care must be taken when setting up work for welding that it cannot be easily displaced and fall to the floor while welding. The result of such an accident may mean serious injury either

from contusions or burns. When welding preheated castings care should be taken of the hose to prevent it coming into contact with the hot metal and being burned, and in general, good care should be taken of the hose to prevent cutting and burning. Hose at best is short-lived and it should be well cared for in order to get the most use out of it possible and to prevent bursting in use. Bursting of the hose under a pressure of even a few pounds is startling if not worse.

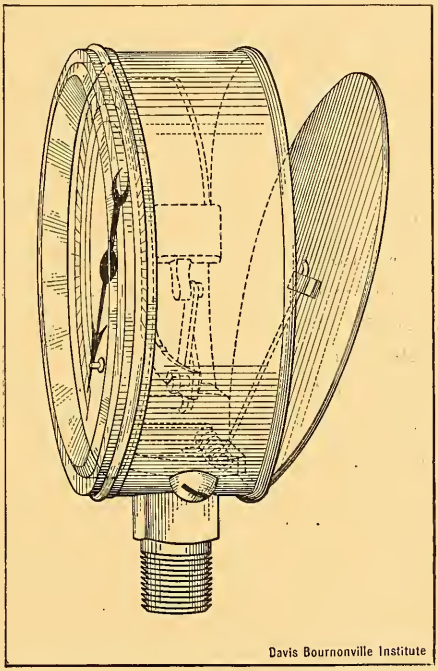

FIG. 9. SAFETY PRESSURE GAUGE. BACK IS HINGED SO THAT IT RELIEVES PRESSURE IN CASE OF FAILURE WITHOUT BLOWING TO PIECES.

Never neglect a leaky joint. If the odor of acetylene is strong find the leak and stop it. A leak is not only costly but dangerous and should never be tolerated under any circumstances whatsoever.

If acetylene is generated on the premises it should be put in the care of an intelligent careful man who should be instructed

how to charge and recharge according to directions. The generator house should be kept locked and should be located away from boilers, furnaces and flying sparks from passing locomotives.

Cylinders containing acetylene and oxygen should never be exposed to the heat of furnaces nor should they be left standing in the sun on hot summer days without protection. The heat may expand the gases and increase the pressure to a dangerous point and even if no accident results the safety plugs may blow and waste the gases.

Fire protection should be provided in the welding shop either in the form of fire pails, chemical extinguishers, or sprinkler heads. A portable extinguisher is an important part of the general equipment and it is advisable to take one along when going out on a field job. An extinguisher will serve to put out a small fire which if it gains headway may result in a serious disaster.

The skill of an oxy-acetylene welder and the conscientiousness with which he does his work are important safety factors. A poorly welded job may fail and cause loss of life or limb and the destruction of property. The welder should therefore have constantly in mind the things he should and should not do for the safety of himself and apparatus, and also to insure dependable work that will not imperil others when in use.

Dont's for Welders and Cutters

Don't connect a regulator to a cylinder without cleaning off the joints.

Don't open a cylinder stop valve quickly.

Don't open a cylinder stop valve part way; open it as far as it will go.

Don't connect the hose to the torch without blowing out.

Don't open a cylinder stop valve without making sure that the regulator handle is released.

Don't open a regulator valve quickly; turn the handle slightly at first and give the diaphragm a chance to operate.

Don't stand close to the regulator when opening the cylinder valve.

Don't use a defective pressure gauge.

Don't use oil or grease on any oxygen connection that comes in contact with the gas.

Don't leave a welding outfit with the gas turned on; always shut the cylinder valves when leaving.

Don't try to adjust the regulator with the torch needle valves closed.

Don't neglect to put in the right size tip when starting to weld.

Don't neglect to adjust the regulator so that the working pressure is correct for the thickness of metal to be welded.

Don't stand behind an oxygen high pressure gauge when opening the cylinder valve.

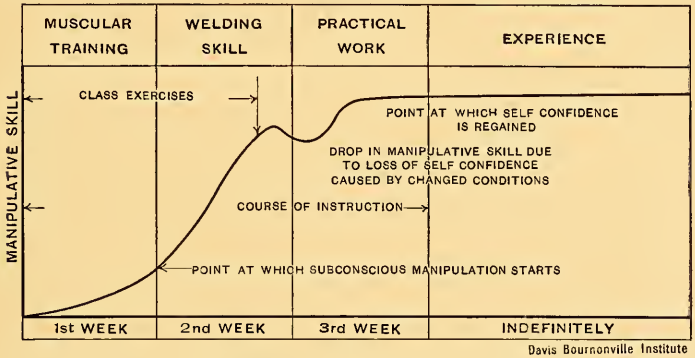

FIG. 10. CHART ILLUSTRATING PROGRESS OF WELDERS WHEN LEARNING. ACCIDENTS LIKELY TO HAPPEN IN THIRD WEEK.

Don't use a regulator with a leaky valve.

Don't use matches to light the torch; use a flint ignitor.

Don't use a porous or leaky hose.

Don't let oil drip on the hose.

Don't let the hose become overheated from close contact with a preheated casting.

Don't let flashbacks burn in the head; close the oxygen valve at once.

Don't turn on the acetylene cylinder valve first in starting to weld.

Don't open the oxygen needle valve first when lighting the torch.

Don't fail to wear goggles to protect the eyes.

Don't wear ragged clothes likely to catch fire when welding or cutting.

Don't fail to wear an apron or overalls.

Don't wear broken shoes in a welding shop.

Don't neglect the torch; hang it up when through welding.

Don't use the torch head as a hammer.

Don't let the tip drop into the puddle.

Don't let the tip of the white hot cone touch the molten metal.

Don't fail to give the torch a semicircular zig-zag motion on prepared joints.

Don't use ordinary iron or steel wire for adding material.

Don't use common cast iron welding sticks.

Don't try to make your own fluxes.

Don't waste flux.

Don't let tips lie around on the welding table; keep them covered in a box.

Don't try to remove the head of a torch from the tubes.

Don't fail to clamp the hose firmly to the nipples.

Don't lay an acetylene cylinder down flat on its sides.

Don't use acetylene too fast from a cylinder.

Don't neglect the odor of acetone when welding; you are using the acetylene too fast.

Don't leave gases under considerable pressure in cylinders; use as much as you can before returning an "empty".

Don't neglect to put the cylinder cap over the cylinder when returning it to the manufacturer.

Don't move cylinders about the plant with the regulators in place; always take them off.

Don't pull on the regulator with the hose.

Don't let an acetylene or oxygen cylinder stand near a furnace or boiler.

Don't let an acetylene or oxygen cylinder stand out in the hot sun when fully charged without protection.

Don't handle gas cylinders roughly either when filled or empty.

Don't let an oxygen cylinder stand beneath a dripping line-shaft.

Don't let an oxygen cylinder get oily or greasy.

Don't let acids drip on gas cylinders.

Don't test a pressure valve with oil; use water or glycerine.

Don't melt the welding rod with the torch flame.

Don't neglect to break down the sides of the vee when welding.

Don't forget that the puddle must melt the adding material.

Don't use a $\frac{1}{16}$ inch welding wire on a $\frac{3}{8}$ inch weld.

Don't use square or twisted wire adding material.

Don't let adding material get rusty.

Don't fail to bevel the edges when preparing to weld.

Don't overheat brass or bronze when welding or brazing.

Don't try to weld a broken malleable iron casting; braze it instead.

Don't forget that a brazed joint is very strong and often preferred to a welded joint.

Don't forget to support aluminum under the weld.

Don't try to weld aluminum without using a puddling stick.

Don't forget that aluminum can be welded smoothly with flux.

Don't overheat an aluminum casting.

Don't use the torch flame for preheating; it is too expensive.

Don't forget that high carbon steel melts at lower temperature than low carbon steel, and is easily burned.

Don't forget that cast iron melts at a lower temperature than steel and that it requires scaling powder.

Don't go into an acetylene generator house with a lighted pipe, cigar or cigarette.

Don't neglect to remove all the residuum when recharging an acetylene generator.

Don't neglect a leaky pipe joint in an acetylene line.

Don't force carbide into the opening of a generator with a metal rod; a spark might be struck that would ignite the gas.

Don't forget to blow off the acetylene and air mixture in a generator when first starting.

Don't undertake to weld or solder an acetylene generator shell without filling it with water to force out all gas.

Don't do any welding or soldering on an acetylene generator if there are other generators in the same room. Remove the

generator before making the repair.

Don't let an acetylene generator run on a pressure of more than 15 pounds per square inch.

Don't forget to keep the backfire or flashback chamber filled with water to the level of the overflow plug.

Don't let any foreign substances go into the hopper of an acetylene generator with the carbide.

Questions

1. Why should you be careful in handling an oxy-acetylene welding outfit?
2. What is the pressure in an oxygen cylinder when received from the manufacturer?
3. How does the pressure in an oxygen cylinder compare with the pressure in a steam boiler?
4. What might be the effect on an oxygen or acetylene cylinder if set close to a furnace or if left out in the sun on hot days?
5. How is acetylene stored in an acetylene cylinder?
6. What happens if the acetylene is drawn off too rapidly?
7. How can you tell when gas is being drawn too rapidly from an acetylene cylinder?
8. How should one proceed to find a gas leak in an acetylene pipe?
9. Why should a welder wear colored glasses?
10. When may spectacles with colored glasses be worn? When should goggles be worn?
11. How would you determine whether a pair of goggles were suitable for your eyes?
12. What causes pitting of colored glasses?
13. Did you ever see colored spectacle glasses pitted on the inside? How could that be possible? What does it show?
14. What precaution should be taken with all goggles when used by a number of welders?
15. What provision is made to prevent the expensive colored glass in goggles becoming pitted?

16. What kind of shoes is safest in a welding shop, foundry or other place where molten metal is liable to fall on the feet?
17. What should be done when the flame flashes back in the torch?
18. What precaution should be taken with hose?

DAVIS-BOURNONVILLE
OXY-ACETYLENE WELDING AND CUTTING
COURSE OF INSTRUCTION

GLOSSARY

Terms used in Oxy-Acetylene Welding and Cutting

DAVIS-BOURNONVILLE INSTITUTE
JERSEY CITY, N. J.

Form 397

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GLOSSARY

Definitions of terms and words used in oxy-acetylene welding and cutting, together with chemical names and formulas.

Acetone. (C_3H_6O) An inflammable liquid of distinctive odor and biting taste made by the destructive distillation of wood. It has remarkable solvent power for acetylene gas, the absorptive capacity being 24 to 25 volumes acetylene per volume of liquid per atmosphere. Used as the solvent liquid in acetylene cylinders.

Acetylene. (C_2H_2) A combustible gas of high thermal value made by slaking calcium carbide with water, and used for welding, cutting, lighting and cooking.

Acid Sodium Carbonate ($NaHCO_3$) Bicarbonate of soda or common baking soda (saleratus).

Adapter. A screw fitting for coupling pressure regulators to cylinders and provided with right or left hand threads, or both, of various diameters to fit.

Adding Material. The filler rod used in welding. Also called welding rod or welding wire.

Adhesion. Condition in a weld resulting from imperfect union and little penetration, comparable to a glued or cemented joint.

Agitator. The revolving paddle of an acetylene generator for stirring up the residuum before discharging it to the sewer.

Alignment. The state of being in line or in the original relation. A broken curved casting is in alignment when the parts are placed in the original relation.

Alloy. A homogenous mixture of two or more metals.

Ammonia. (NH_4OH) Spirits of hartshorn, the aqueous solution of gaseous ammonia, NH_3.

Ammonium Chloride. (NH_4Cl) Sal-ammoniac.

Angle Bar. A rolled steel bar the cross section of which is usually an angle of 90 degrees.

Anode. The negative electrode of an electrolytic generator on which the hydrogen gas collects.

Aqua Regia. A mixture of nitric and hydrochloric acids in the proportion of 1 part nitric acid to 3 parts hydrochloric. Used for dissolving gold and for etching metals.

Asbestos. A mineral substance composed mainly of magnesium silicate, which is spun, woven or felted and having high heat-resisting and insulating qualities. Used for protecting work when preheating and after welding.

Asbestos Blanket. The woven absestos fabric of an electrolytic generator to separate the gases.

Atmosphere. The pressure of the air at sea level, 14.7 pounds per square inch. A pressure of 10 atmospheres is 147 pounds per square inch.

Autogenous. Self-produced, and as applied to welding, meaning the welding of metals by fusing without the use of additional metal and without hammering. The term is loosely applied to all gas welding with or without the use of adding material.

Babbitt. An anti-friction metal used for lining bearings. The original babbitt formula is said to be about 50 parts tin, 2 parts copper and 4 parts antimony.

Backfire. Penetration of a flashback through the torch into the handle, hose or pressure regulator. A backfire is caused by firing an accumulation of mixed gases, due generally to faulty manipulation of the cylinder stop valves, improper regulator adjustment, incorrect procedure in turning on and lighting the gas, or dipping the tip into the molten metal. See Flashback.

Bearings. The support or wearing surface in a box or a revolving shaft. See Journal.

Bell. A receiver for storing gases, consisting of an inverted metal cup floating in water and water sealed at the mouth.

Bevel. An angle of other than 90 degrees formed on the margin of a plate or casting when prepared for welding.

Blowhole. A hole or cavity in metal formed by gas.

Blow-off Valve. Hand operated safety valve of an acetylene generator to clear the chamber of air and acetylene mixture after charging.

Blowpipe. Originally a straight or curved pipe used by workers of precious metals for blowing an alcohol flame against the parts to be melted or soldered. A gas burner in which the combustible gas and air or oxygen are mixed and burned to produce a high temperature flame. The term "torch" is given the preference in America when applied to the oxy-acetylene apparatus for welding and cutting.

Bourdon Tube. The flattened curved tube of a pressure gauge which tends to straighten under internal pressure.

Bottle. A pressure container for transporting acetylene, oxygen, hydrogen or other gas. See Tank or Cylinder.

Brazing. A process of uniting metals by heating with a brass or bronze alloy of low fusing temperature. Also called hard soldering.

Burning. Applied to lead, meaning the process of joining lead sheets for acid tanks by autogenous welding.

Burning on. The process of replacing part of a broken casting in the foundry by pouring molten iron through a sand mold containing the casting until it is preheated and fused along the margins of the broken parts when the pouring is stopped and the metal permitted to cool and unite.

Butt Joint. A seam made by butting two edges together.

By-pass. Passage in the cutting torch connecting the oxygen supply with the preheating oxygen tube.

Calcium Carbide. (CaC_2) Material used for the production of acetylene gas by slaking with water.

Calcium Chloride. ($CaOCl_2$) Chloride of lime. Bleaching powder.

Calcium Hydroxide. ($Ca(OH)_2$) Slaked lime.

Calcium Oxide. (CaO) Quick lime.

Camograph. A hand-operated torch cutting machine for cutting slotted holes in rails.

Cap. The metal protector screwed over a cylinder stop valve to prevent injury in transit.

Carbide Filling Plug. The screw plug in the top of an acetylene generator which is removed when filling the hopper.

Carbon Dioxide. (CO_2) A product of perfect combustion of carbon, a heavy colorless incombustible gas.

Carbonite. Carbon compressed into rods and sheets used as a fire resisting dam in building bosses, lugs, gear teeth and other parts. Also called carbon blocks.

Carbonizing. Having the quality of imparting carbon and meaning, when applied to the torch flame, an excess of combustible gas which deposits carbon in the molten metal. See Carburizing.

Carbon Monoxide. (CO) Product of imperfect combustion.

Carburizing. Same as carbonizing, but preferable for carbon imparting.

Casehardening. The process of carburizing the surface layers of mild steel and raising the carbon content to the point where the steel will harden when heated to a cherry red and dipped in water.

Cathode. The positive electrode of an electrolytic generator on which the oxygen gas collects.

Cell. An electrolytic generator unit.

Channel. Structural shape having flanges turned on each side forming a trough.

Chipping. Removing metal with a hammer and chisel.

Coefficient. The factor used to determine the expansion of metals by heat. Generally expressed per one degree change of temperature F. The coefficient of expansion of steel is 0.00000636.

Cohesion. Condition resulting from perfect fusion and penetration which locks the molecules of parent metal and adding material together.

Column. A vertical support made of structural steel or cast iron.

Combustible. Anything that burns in the air or an atmosphere of oxygen. Same as Inflammable.

Compressor. A water cooled gas pump for compressing oxygen, hydrogen, or acetylene into cylinders.

Connector. A fitting for joining lengths of hose.

Content. The quantity of a material contained in a metal, such as the carbon, nickel or titanium content of steel.

Contraction. The shrinkage of metal in cooling.

Copper Sulphate. ($CuSO_4$) Bluestone or blue vitriol.

Countersink. To bevel the edge of a hole to fit the tapered head of a bolt or rivet.

Coupling. A threaded sleeve for joining pipes.

Conical Seat. The joint in the torch head fitting the interchangeable tip.

Creeping. The building up of pressure in a pressure regulator when not in use. Caused by gas leaking through the regulating valve.

Cross Bar. The handle of the regulating screw of a gas pressure reducer or regulator.

Cutting. The term applied to the burning of wrought iron, steel, and cast iron with a jet of oxygen.

Cutting Torch. A torch or blowpipe with one or more heating jets and an oxygen jet, used for cutting iron and steel.

Cylinder. A pressure container for holding gas under pressure. Also called Tank and Bottle.

Cylinder Filler. The porous contents of an acetylene cylinder made of asbestos, charcoal, infusorial earth and cement, compacted to completely fill and leave no open space for the collection of free acetylene gas under pressure.

Cylinder Valve. The outlet stop valve of a gas cylinder.

Dial. The graduated face of a pressure gauge.

Diaphragm. The flexible partition in a regulator beneath the regulator spring. Also the partition in a high pressure gauge to protect the glass from being blown out when the Bourdon tube bursts.

Dissociation. Separation attended by the release of heat such as develops intensely in the combustion of acetylene with oxygen in the torch and produces the white hot cone having a temperature of about 6300 degrees F. Dissociation of acetylene may result from over-pressure and shock.

Drift. A tapered hand punch for enlarging and lining up rivet holes in plates.

Ductile. That which can be drawn or stretched.

Ductility. The property of iron, steel, copper, brass and other metals which permits them to be drawn into wire.

Duograph. A motor driven torch welding machine for

welding cylinders, containers, steel barrels, etc.

Elastic Limit. The maximum load sustained by a test bar just before it begins to stretch.

Electrode. Either of the poles of an electrolytic cell. Oxygen is liberated on the positive electrode and hydrogen on the negative electrode.

Electrolyte. The water and caustic soda solution in an oxygen and hydrogen electrolytic generator.

Elongation. The stretch of a bar when pulled apart in a testing machine. Generally expressed in percentage of a definite length of the specimen.

Endothermic. Pertaining to the absorption of heat. Acetylene gas is an endothermic substance, heat being absorbed in the reaction of calcium carbide and water by which it is produced. Few chemical compounds are endothermic.

Etching. Corroding a polished metal surface with acid or other chemical to show the physical structure.

Exothermic. Pertaining to compounds whose formation is attended with development of heat, and whose dissociation absorbs heat. Most chemical compounds are exothermic.

Expansion. The increase in length, breadth and thickness of metals due to heat.

Feeding Disc. Revolving plate on which the carbide drops from the hopper of an acetylene generator when feeding.

Filler Rod. The adding material or welding rod used to fill a welded joint. Also called Adding Material and Welding Rod.

Fillet. The material used to fill a corner and to round the angle.

Filter. An apparatus for removing dust and floating impurities from acetylene gas.

Flame. The combustion of gas.

Flashback. Snapping out of the flame and penetration of the flame into the torch mixing chamber but no further. A flashback is generally caused by an obstruction in the tip or by overheating of the tip and head. See Backfire.

Flux. Any material used to dissolve oxides, to release trapped gases and slag and to clean metals for welding and

soldering.

Fracture. A break. Applied to broken metal surfaces.

Fuse. To melt.

Fusing. Melting (with heat).

Gas. The form of matter usually invisible which may be indefinitely compressed and expanded, having no coherence or form, such as acetylene, oxygen, hydrogen, nitrogen, chlorine, etc.

Gasometer. A bell or receiver for storing gases. See Bell.

Gauge. An instrument usually having a circular graduated dial and movable hand for measuring pressures of gases in pressure containers.

Generator. An apparatus for producing gas and usually applied to the means for producing acetylene or oxygen.

Girder. A beam of I section built of plates and angles.

Goggles. Colored glasses for protecting the eyes from destructive heat and light rays.

Grain. The arrangement of the large crystals visible in a metal fracture.

Handle. The part of the torch held in the hand.

Handwheel. Any disc or wheel handle of a valve or other apparatus.

Holograph. A hand operated torch cutting machine for cutting holes in the webs of rails and structural steel.

Hopper. The receiver for calcium carbide in an acetylene generator.

Horizontal. Level or parallel with the horizon. Applied to welding in a level position.

Hose. Flexible rubber pipe reinforced with fabric. Used to connect the torch with the sources of gas supply.

Hydrochloric Acid. (HCl) Muriatic acid.

Hydrogen. (H) A colorless, odorless, combustible gas, the lightest known. Used for welding and cutting.

I-Beam. A structural shape having a cross section like the letter I.

Inflammable. That which can be burned. Same as Combustible.

Interchangeable. That which can be interchanged, like the tips of Davis-Bournonville cutting and welding torches.

Jet. The stream of gas issuing from a torch tip.

Journal. The wearing surface of a revolving shaft in a bearing. See Bearing.

Kerf. The fissure made in iron or steel by the cutting torch.

Key. The handle used to open and close a cylinder stop valve.

Laminated. Composed of sheets in layers.

Lead Carbonate. ($PbCO_3$) White lead.

Lead Oxide. (PbO) Litharge.

Line. A metal pipe or rubber hose for gas.

Liquefaction. Reducing a gas to the liquid state by compression and refrigeration.

Magnetograph. A hand operated torch cutting machine for cutting holes in ship plates, provided with magnets to hold the machine in place.

Main. The principal distributing pipe of a gas line system.

Malleable. That which can be shaped by hammering, bending or drawing.

Manifold. A metal header or multiple connection for connecting several gas cylinders to a pipe line.

Mercury. (Hg) Quicksilver.

Mild. Applied to steel to indicate low carbon content and characteristics similar to wrought iron.

Mixing Chamber. That part of the torch in which the combustible gas and oxygen are brought together.

Monel. A natural alloy of copper and nickel.

Motor. Weight or spring-driven clockwork mechanism for revolving the feeding disc of an acetylene generator.

Muriatic Acid. (HCl) Hydrochloric acid.

Needle Valve. A small valve with a conical seat capable of fine adjustment and used in cutting and welding torches for regulating the gas mixture.

Neutral. Applied to flame meaning neither carbonizing nor oxidizing.

Nipple. A short piece of screwed pipe.

Nitric Acid. (HNO_3) Aqua fortis.

Nozzle. The discharge part of an apparatus. Sometimes applied to the tip of a torch.

Overhead. Applied to joints in a ceiling or overhead.

Oxide. Combination of oxygen with metal generally in the form of rust, corrosion, coating, film or scale.

Oxidization. Combining with oxygen and forming an oxide.

Oxidizing. Applied to the torch flame meaning a flame containing an excess of oxygen gas which burns the molten metal.

Oxygen. The supporter of combustion comprising about one-fifth the atmosphere. Furnished commercially pure, compressed in cylinders to a pressure of 1800 to 2000 pounds pressure per square inch for torch welding and cutting.

Oxygraph. A machine cutting torch mounted on a pantagraph reducing gear with a motor driven tracing wheel, so designed that a drawing can be traced and reproduced in the part cut out with the torch.

Parent. The metal welded. Used to distinguish the parts welded from the adding material or welding rod.

Peening. Stretching cold metal by striking with the peen of a hammer.

Penetration. Welding clear through the joint. Indicated by the molten metal appearing in drops or globules on the far side.

Pet-cock. A small discharge valve with a plug or key requiring a 90-degree turn to open or close.

Photomicrograph. Photograph of microscope enlargement of a metal specimen.

Plumb-bob. A weight with conical tip suspended with string to show the vertical line.

Pole. One of the two terminals of an electrolytic generator, know as positive and negative.

Polymer. Product of high temperature generation in an acetylene generator.

Polymerization. The effect of high temperature in acety-

lene generators which is shown by the presence of yellow tarry deposits.

Pool. The small body of molten metal formed by the torch flame. Also called Puddle.

Potassium Carbonate. (K_2CO_3) Potash.

Potassium Chlorate. ($KClO_3$) Chlorate of potash.

Preheating. Heating metal plates or castings previous to welding in order to minimize expansion and contraction stresses and to save gas.

Pressure. The force exerted by a confined gas or liquid. Measured in pounds per square inch.

Pressure Reducer. An apparatus for reducing and regulating the pressure of gases used for welding and cutting.

Pressure Regulator. An apparatus for maintaining a nearly constant pressure of the gases used for welding and cutting. All pressure regulators are reducing valves, and operate by lowering the pressure of gas supplied from cylinders, generators or pipe line systems to the working pressure required.

Puddle. The fused body of metal directly beneath the torch flame. Also called the Pool.

Puddle Stick. A steel rod flattened at the end and formed in various shapes for breaking up oxides and removing slag. Used especially in welding cast aluminum without flux.

Puddling. The breaking up of oxide and elimination of slag and oxide from the puddle, especially when welding cast aluminum without flux.

Purifier. An apparatus for removing sulphurreted hydrogen and other gases from acetylene.

Pyrograph. A torch cutting machine for beveling and trimming flanged boiler heads and boiler plates.

Radiagraph. A motor driven torch cutting machine for cutting straight lines or circles in steel and iron plate.

Reaction. The change resulting from a chemical combination or a mechanical action.

Reducing. Applied to flame, meaning carbonizing or carburizing, the opposite of oxidizing.

Regulator Screw. The part of a pressure regulator by

which the tension of the diaphragm spring is adjusted.

Residuum. The sludge or accumulation of water and slaked lime in the bottom of an acetylene generator.

Ribbon Flame. The torch flame produced with a tip having a narrow slot orifice.

Ripple. A general characteristic of steel welds made with the hand torch, similar in appearance to the surface of water under an air current.

Safety Disc. A sheet brass disc in combination with a fusible alloy designed to blow out under excessive pressure or heat or both.

Safety Valve. A fitting connected to a gas pipe system containing a metal diaphragm designed to blow out when gas pressure exceeds a certain figure.

Scale. The coating of oxide on (molten) iron and steel.

Scaling Powder. Flux used for dissolving oxides formed in cast iron welding.

Screen. A fine mesh wire cloth part to prevent foreign matter entering the regulator or torch. See Strainer.

Scrubbing. An apparatus for removing ammonia, dust and other free impurities from acetylene gas. More elaborate than a washer. See Washer.

Seam. A joint welded or unwelded. Applied generally to thin metal.

Seat. The surface against which a valve disc is held when closed.

Shell. The circular part of a cylinder.

Side Seam. Applied to welding, meaning a horizontal seam in the side of an upright part.

Slag. Oxidized metal and other impurities formed in welding and liable to be trapped in the molten state. Also applied to the oxidized metal and scale blown out when cutting iron and steel.

Sludge. The accumulation of slaked carbide in the bottom of an acetylene generator.

Sludge Valve. The discharge valve for removing residuum from an acetylene generator.

Sodium Carbonate. (Na_2CO_3) Carbonate of soda or

soda ash.

Sodium Chloride. ($NaCl$) Common salt.

Sodium Hydroxide. ($NaOH$) Caustic soda. Used in the electrolyte of oxygen and hydrogen generators.

Sodium Silicate. ($Na_2Si_4O_9$) Water glass.

Sodium Sulphate. (Na_2SO_4) Glauber's salts.

Sodium Tetraborate. ($Na_2B_4O_7$) Borax. Crystalline borax contains ten parts water, its formula being $Na_2B_4O_7+10H_2O$. Calcining or burning borax drives off the water of crystallization.

Solder. A fusible alloy used for uniting metals. The soft solders melt at a comparatively low temperature and are alloys of lead and tin. The hard solders melt at higher temperatures and are usually alloys of zinc and copper.

Soldering. The process of uniting metals by fusing an alloy of low melting temperature and heating the parts to be joined to the amalgamating temperature.

Spectacles. Colored glasses with steel or aluminum frames and generally without side shields for protecting the eyes.

Spelter. Hard solder, usually a one-to-one alloy of copper and zinc.

Spoon. A wire flattened at the end for smoothing the surface of an aluminum joint welded without flux.

Stirrup. The yoke connecting the diaphragm of a pressure regulator and the valve disc.

Straightedge. Generally a steel bar with one edge planed straight and beveled. Used for lining up.

Strainer. A part made of fine mesh wire cloth through which the gas passes and which stops the passage of dirt and foreign matter.

Stuffing Box. The provision made for preventing gas leaking around the needle valve stems and high pressure valve stem of the cutting torch, etc.

Sulphuric Acid. (H_2SO_4) Vitriol or oil of vitriol.

Sweating. Soldering broad metal surfaces by coating the surface with solder, clamping the parts together and applying heat.

Tacking. Uniting metal parts with spots or buttons of fused metal.

Tank. A pressure container for transporting acetylene, oxygen, hydrogen or other gas. See Cylinder or Bottle.

Tinning. The process of coating metals with tin. Also applied to the preparation of tool steel for welding with machinery steel by coating the tool steel with adding material before welding.

Tip. The copper or brass nozzle of the welding or cutting torch.

Torch. A gas burner or blowpipe for welding or cutting.

Torch Bushing. The nut for holding the tip in the torch head.

Torch Head. The part of a welding or cutting torch carrying the tip.

Torch Tube. The pipe connecting the torch head and handle.

Ultimate Strength. The maximum load sustained by a test bar before rupture.

Union. A pipe coupling in parts held together with a nut. Used where pipes may require disconnection.

Valve. The means for shutting off the flow of gas or liquid.

Vee. The angle or groove between two beveled edges when prepared for welding.

Vee Block. A block cut out in the shape of a vee or angle, and used for supporting shafts in line when welding.

Vent Valve. Water sealed trap for discharging the excess water in an acetylene generator. Also a safety device to indicate the presence of an obstruction in the vent pipe.

Vertical. Applied to welding, meaning a seam in an upright or vertical position.

Washer. An apparatus for removing ammonia and dust from acetylene gas. See Scrubber.

Water Seal. A safety device to prevent backfires being propagated through a pipe line to the generator.

Welding Rod. The metal used to supply the filler required in a welded joint. Also called Adding Material and

Filler Rod.

Welding Sticks. Adding material or welding rod of cast iron, cast aluminum and other cast metals.

Welding Table. Metal table for supporting work for welding.

Welding Wire. Wire adding material of the smaller gauges.

Z-Bar. Structural shape having cross section similar to the letter Z.

Zinc Chloride. ($ZnCl_2$) Chloride of zinc or tinner's acid.

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